Acta Geologica Polonica, Vol. 54 (2004), No. 3, pp. 339-367

The position and age of the youngest deposits in the Mszana Dolna and Szczawa tectonic windows (Magura Nappe, Western Carpathians, Poland)

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ABSTRACT:

OSZCZYPKO-CLOWES, M. & OSZCZYPKO, N. 2004. The position and age of the youngest deposits in the Mszana Dolna and Szczawa tectonic windows (Magura Nappe, Western Carpathians, Poland). *Acta Geologica Polonica*, **54** (3), 339-367. Warszawa.

The Mszana Dolna and Szczawa tectonic windows are composed of deposits belonging to the Fore-Magura Group of units. The central and most uplifted part of these windows are dominated by relatively flat laying deposits belonging to the Krosno Formation (Oligocene) of the Dukla Unit. The western, eastern and southern marginal parts of the Mszana Dolna tectonic window are occupied by strongly tectonized, Cretaceous-Oligocene deposits assigned to the Grybów Unit. The Szczawa tectonic window is entirely built up of Oligocene deposits of the Grybów Unit. The youngest deposits of the Mszana Dolna tectonic window are correlated with zone NP24 (Dukla Unit) and NP23-NP25 (Grybów Unit). In the Szczawa tectonic window (Grybów Unit), the NP22-NP24 Zone was determined in the Grybów Beds, whereas the Cergowa Beds belong to zone NP24.

Such age determination corresponds well with that of the southern part of the Silesian and Dukla units. The deposits of the Dukla and Grybów units are tectonically covered by the Cretaceous-Eocene deposits of the Magura Nappe. During the latest Oligocene a thrusting of the Magura Nappe onto the Fore-Magura sedimentary basin began (Grybów and Dukla). This process was probably initiated under the submarine condition. The last of the over thrusting stages took place probably during the Middle Miocene, and resulted in the development of the Mszana-Dolna duplex structure.

Key words: Tectonic windows, Oligocene, Dukla, Grybów and Magura units, Western Carpathians.

INTRODUCTION

In the Polish sector of the Magura Nappe eleven tectonic windows have been recognized (Text-fig. 1, see also KSIĄŻKIEWICZ 1977). The majority of these windows are situated between the Kraków meridian on the west, and the Polish/Slovak frontier in the east (Text-fig. 1). To the west of this area SIKORA & ŻYTKO (1959) discovered a small tectonic window in Sopotnia Mała, whereas in Eastern Slovakia the Smilno tectonic window is known since 1880s (UHLIG 1888, NEMČOK & *al.* 2000). These windows belong to the Fore-Magura Group of units, and occupy the intermediate position between the Silesian and the Magura nappes. In the tectonic windows occur the Obidowa Unit, which is regarded as the western prolongation of the Dukla Unit (CIESZKOWSKI & *al.* 1985) and the Grybów Unit (ŚWIDZIŃSKI 1963), known also as the Klęczany-Pisarzowa Unit (KOZIKOWSKI 1953, 1956a, b) These units are composed predominantly of the Late Eocene-Oligocene, sometimes of the Late Cretaceous-Palaeocene deposits. There is a common understanding (see KSIĄŻKIEWICZ 1962, BIEDA & *al.* 1963, GEROCH & *al.* 1967, KORAB & DURKOVIČ 1978), that the Fore-Magura Group of units displays transitional litho-facies, which linked the Silesian and Magura basins. According to these opinions the Upper Cretaceous-Middle Eocene deposits of the Fore-Magura Group of units reveal a similarity to the Magura Nappe facies, whereas the Late Eocene-Oligocene deposits have similar lithological features to those from the Silesian Unit. There is a common opinion that the Grybów succession was deposited between the Magura and Dukla-Silesian sedimentary areas (see BIEDA & *al.* 1963, KSIĄŻKIEWICZ 1977, OLSZEWSKA 1981).

The Late Eocene-Oligocene facies relationships between the Silesian, Fore-Magura group of units and Magura units suggest proximity between the Silesian and Magura basins. This opinion concurs with that on the Late Cretaceous to Eocene, where the interaction between these basins was controlled by vertical movements of the Silesian Ridge, which separated the western part of the Magura basin from the Silesian basin (KSIĄŻKIEWICZ 1956). This concept was recently questioned by NEMČOK & *al.* (2000), who regard the Magura basin a western prolongation of the Silesian basin, explaining the present-day position of the Magura Nappe to be a result of the Middle Miocene, eastward escape of the Alcapa terrain together with the Pieniny Klippen Belt and the Magura Nappe against the Fore-Magura/Silesian group of units. The Magura Nappe is flatly overthrust onto the Fore-Magura Group of units and partly onto the Silesian units (western segment). The results of deep boreholes and the tectonic windows provide us with an idea about the minimal amplitude of the Magura Nappe overthrust, which is at least 35 km on the Kraków-Zakopane geo-traverse (SIKORA 1980). The age of the youngest deposits beneath the Magura Nappe sole thrust determine the time when the overthrusting of this unit begun. Taking into account the occurrence of the Oligocene Krosno Formation in the tectonic windows, the Late Oligocene onset of the Magura Nappe overthrust should be accepted. The discovery of folded Late Oligocene-Early Miocene deposits in the Magura Nappe (OSZCZYPKO & *al.* 1999a, OSZCZYPKO-CLOWES 2001, OSZCZYPKO & OSZCZYPKO-CLOWES 2002) necessitates the revision of the traditional model of the tectonic evolution of the Western Carpathians (KSIĄŻKIEWICZ 1977, BIRKENMAJER 1986, OSZCZYPKO 1992, GOLONKA & *al.* 2000).

The aim of this study was to recognize the age and tectonic position of the youngest deposits of the Mszana Dolna and Szczawa tectonic windows, and their relation to the Magura Nappe.

MSZANA DOLNA TECTONIC WINDOW (MDW)

A characteristic feature of the middle part of the Magura Nappe in the Polish Outer Carpathians is the presence of the Mszana Dolna tectonic window (MDW). The area of the MDW (Text-fig. 2) and its surroundings were the subject of basic geological investigations (see BURTAN & *al.* 1976, 1978; MASTELLA 1988). According to BURTAN & *al.* (1976, 1978) the MDW is composed of the North and South For-Magura units, whereas MASTELLA (1988) referes to them as the Mszana Dolna and Grybów units, respectively. It seems that the central and most uplifted part of this window is dominated by the Oligocene Krosno Formation of the Dukla (Obidowa–Słopnice) Unit (ŻYTKO & *al.* 1989), whereas the narrow, marginal part of the window is occupied by the Cretaceous-Oligocene deposits of the Grybów Unit (Text-fig. 2). POŁTOWICZ (1985) referred all of the Oligocene deposits of the MDW to the Grybów Unit.

Recently, the southern margin of the MDW has been the subject of geological investigations of a second author and his students (see OSZCZYPKO & *al.* 1999b).

The southern periphery of the MDW is one of the best-exposed areas in the Polish Outer Carpathians. Consequently, its lithostratigraphy and architecture of the flysch deposits are relatively well known. The formal and informal lithostratigraphic units are used in parallel for the description of these deposits (see BIRKENMAJER & OSZCZYPKO 1989, OSZCZYPKO 1991, OSZCZYPKO & *al.* 1999b).

Magura Nappe

The southern margin of the MDW is composed of the Cretaceous-Palaeogene deposits of the Magura Unit, which belong to the so-called "south peri-window" zone (BURTAN & *al.* 1976, 1978). According to the most recent geological study, this zone belongs to the Poręba-Koninki and Konina-Lubomierz thrust sheets, which can be correlated with the Rača and Bystrica subunits, respectively (Text-figs 2-3, see also MASTELLA 1988, OSZCZYPKO & *al.* 1999b). The more internal tectonic elements: Tobołów-Turbaczyk thrust sheet of the Bystrica and Krynica Subunits do not directly join with MDW.

Fig. 2. Geological sketch-map of the middle part of the Polish Carpathians (after OSZCZYPKO & *al.* 1999b, supplemented); 1 – Podhale Flysch, 2 – Pieniny Klippen Belt; Magura Nappe: 3 – Krynica Subunit, 4 – Tobołów-Turbaczyk thrust sheet, 5 – Bystrica Subunit, 6 – Rača Subunit, 7 – Siary Subunit, 8 – Grybów Unit, 9 – Dukla Unit, Silesian & Sub-Silesian units, 10 – Miocene onto the Carpathians, 11 – Miocene andesites, 12 – faults, 13 – sampled area, 14 – isobathe of Magura Nappe overthrust, 15 – boreholes, 16 – geological cross-section

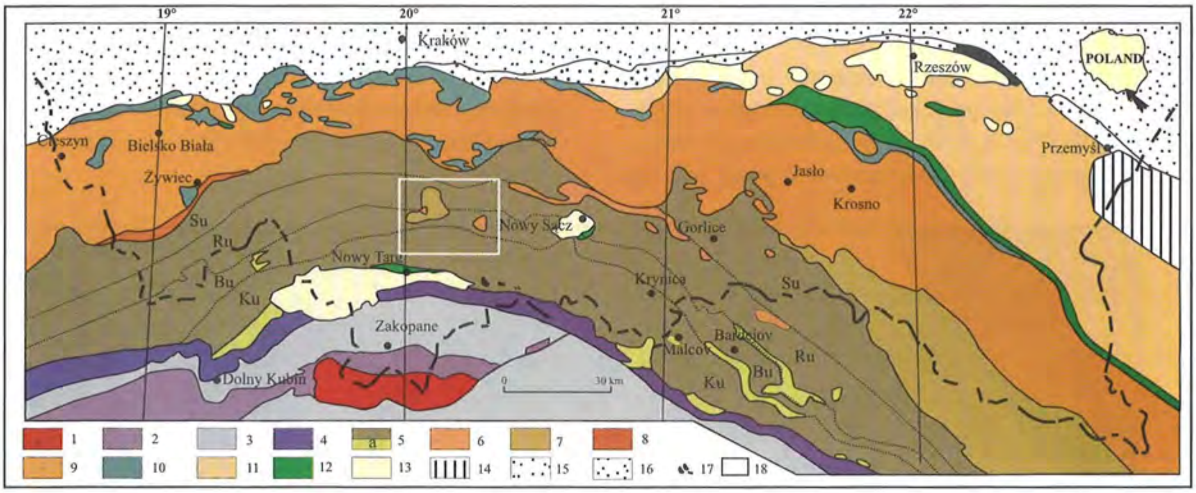
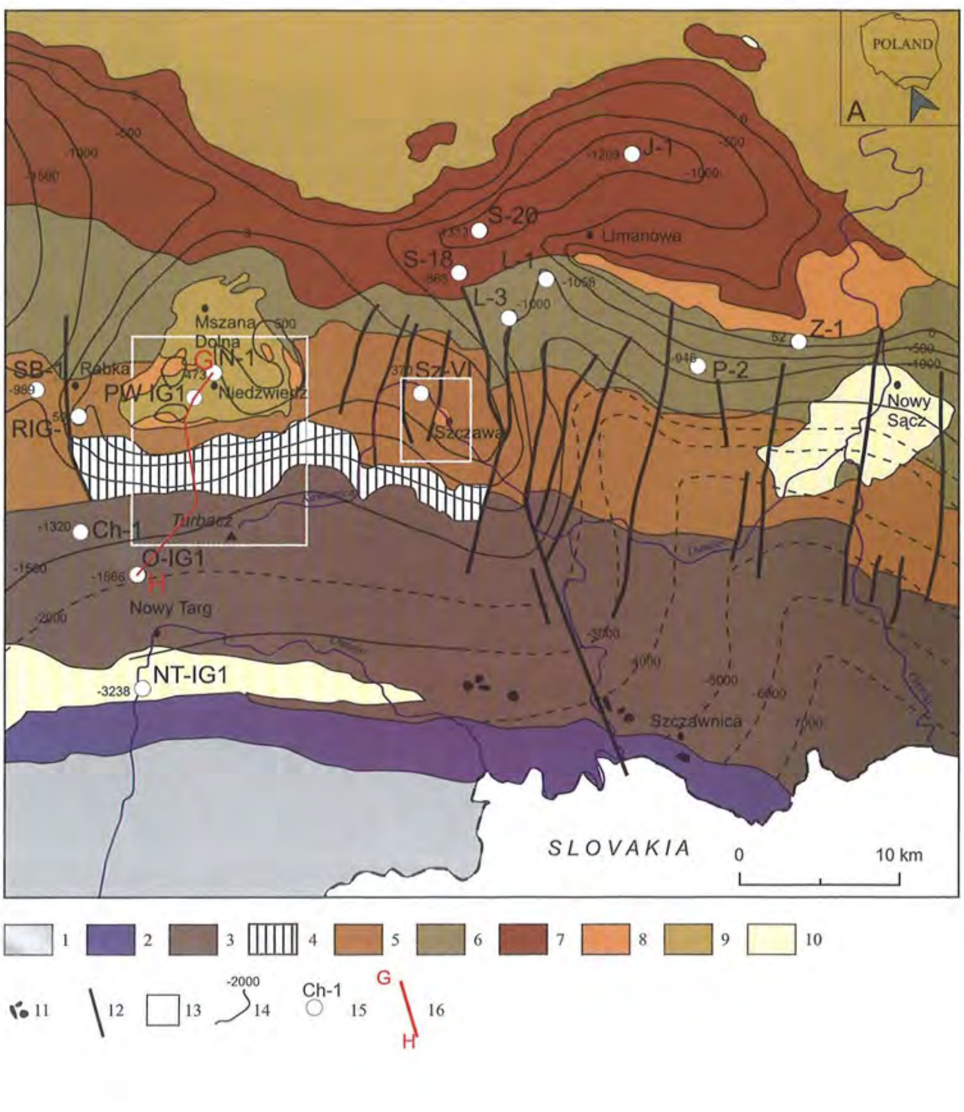


Fig. 1. Tectonic map of the Northern Carpathians [compiled by OSZCZYPKO-CLOWES 2001); 1 – crystalline core of the Tatra Mts., 2 – High Tatra and sub-Tatra units, 3 – Podhale flysch, 4 – Pieniny Klippen Belt, 5 – Magura Nappe, 5a – Malcov Formation, 6 – Grybów Unit, 7 – Dukla Unit, 8 – Fore-Magura Unit, 9 – Silesian Unit, 10 – Sub-Silesian Unit, 11 – Skole Unit, 12 – Lower Miocene, 13 – Miocene deposits upon the Carpathians, 14 – Stebnik (Sambir) Unit, 15 – Zgłobice Unit, 16 – Miocene of the Carpathian Foredeep, 17 – andesite, 18 – studied area; Su – Siary, Ru – Rača, Bu- Bystrica, and Ku – Krynica subunits



Hulina Formation

This formation is known from the basal portion of the Magura Nappe (Poręba-Koniki thrust sheet, Text-figs 4-5). The deposits of the formation are represented by green, spotty shales and are exposed only on the slumped bank of the Koninki stream (Text-fig. 3, see also BURTAN & *al.* 1978, BIRKENMAJER & OSZCZYPKO 1989). The thickness of these deposits, reduced tectonically, does not exceeds 5 m. The Hulina Formation is dated for the ?Albian-Cenomanian (MALATA 2001).

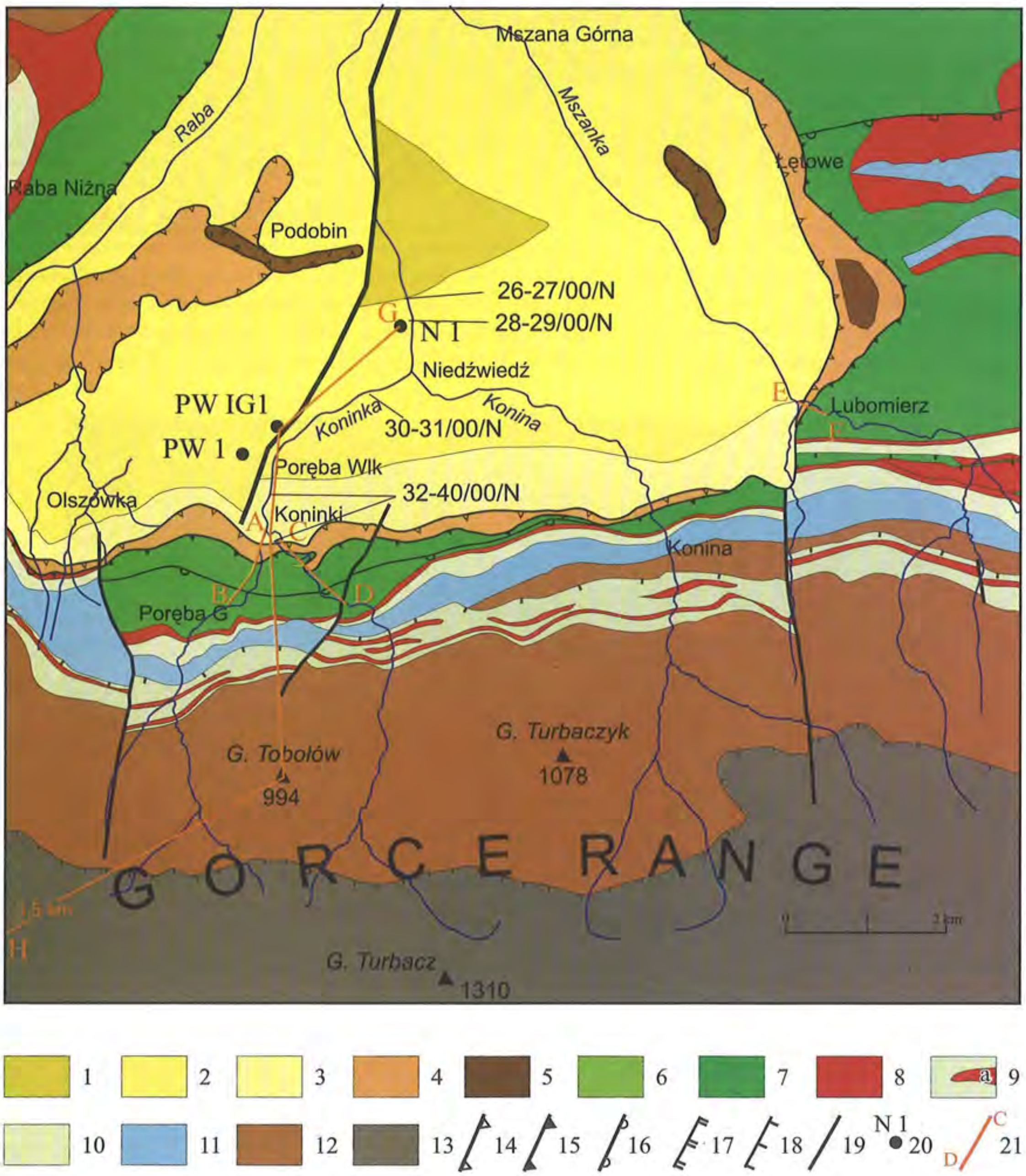


Fig. 3. Geological map of the southern part of Mszana Dolna tectonic window (after BURTAN & *al.* 1976, OSZCZYPKO & *al.* 1999b, changed and supplemented), Dukla Unit; Krosno Beds (Oligocene): 1 – thick-bedded sandstones, 2 – sandstone-shaley facies, 3 – shaley facies; Grybów Unit: 4 – Grybów Unit, undivided, 5 – Menilite Beds (Oligocene); Magura Nappe: 6 – Albian-Cenomanian deposits, 7 – Cenomanian-Palaeocene udivided; Eocene: 8 – Łabowa Formation, 9 – Zarzecze Formation, a – variegated shales, 10 – Beloveza Formation, 11 – Bystrica and Żeleźnikowa formations, 12 – Magura Formation, 13 – Krynica Subunit (Palaeocene-Eocene), 14 – Grybów overthrust, 15 – Magura overthrust, 16 – Bystrica overthrust, 17 – Bystrica Subunit internal overthrusts, 18 – Krynica overthrust, 19 – faults, 20 – borehole, 21 – cross-section

Malinowa Shale Formation

The Hulina Formation is overalaid by variegated, mainly red shales of the Malinowa Formation, which usually form the base of the Magura Nappe sequence (BIRKENMAJER & OSZCZYPKO 1989; MALATA & OSZCZYPKO 1990). In the Poręba Górna-Koninki-Lubomierz area the thickness of this formation is at least 30 m (Text-figs 4-7). In the Koninki section the Malinowa Formation is of the Turonian-Santonian age (MALATA 2001).

Kanina Beds

The Campanian-Palaeocene turbiditic deposits, overlying the Malinowa Formation, followed by the Early Eocene variegated shales of the Łabowa Formation, are traditionally referred to as the "Inoceramian Beds", though the name Ropianka Beds has also been used. On the southern margin of the MDW, these deposits may further be subdivided lithostratigraphically (OSZCZYPKO 1992, OSZCZYPKO & *al.* 1999b; see also BURTAN & *al.* 1976, 1978). In the Olszówka-Lubomierz area these deposits are 100-250 m thick and can be subdivided into three members.

The lower member (=Kanina Beds) (see Burtan 1976, 1978; OSZCZYPKO 1992, OSZCZYPKO & *al.* 1999b) is composed of thin- to medium-bedded, very fine to fine-grained calcareous sandstones, displaying Bouma's T_{bc}, $T_{c+ conv}$ turbidite intervals. The basal portion of the

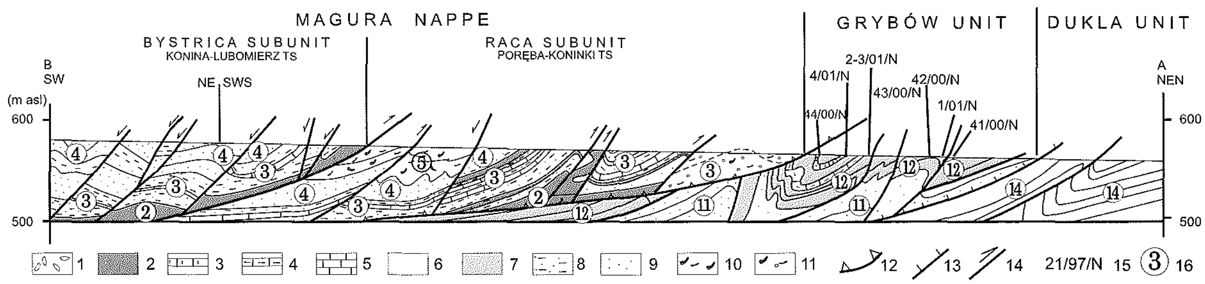


Fig. 4. Geological cross-section through the southern margin of the Mszana Dolna tectonic window, along the Poręba Górna stream; 1 – spotty shales, 2 – variegated shales, 3 – spherosiderites, 4 – marls, 5 – turbidite limestones, 6 – calcareous shally flysch facies, 7 – black marly sheles, 8 – thin to medium-bedded turbidites, 9 – thick-bedded sandstones, 10 – submarine slumps, 11 – chaotic deposits, 12 – Magura overthrust, 13 – Grybów thrust, 14 – fault, 15 – sample, 16 – lithostratigraphic units: 1 – Hulina Formation, 2 – Malinowa Shale Formation and Haluszowa Formation, 3 – Kanina Beds, 4 – Szczawina Ss., 5 – Ropianka Beds, 6 – Łabowa Shale Formation, 7 – Belovcza Formation, 8 – Bystrica Formation, 9 – Żeleźnikowa Formation, 10 – Maszkowice Member of the Magura Formation, 11 – Jaworzynka Beds, 12 – Grybów Beds, 13 – Cergowa Beds, 14 – Krosno Beds

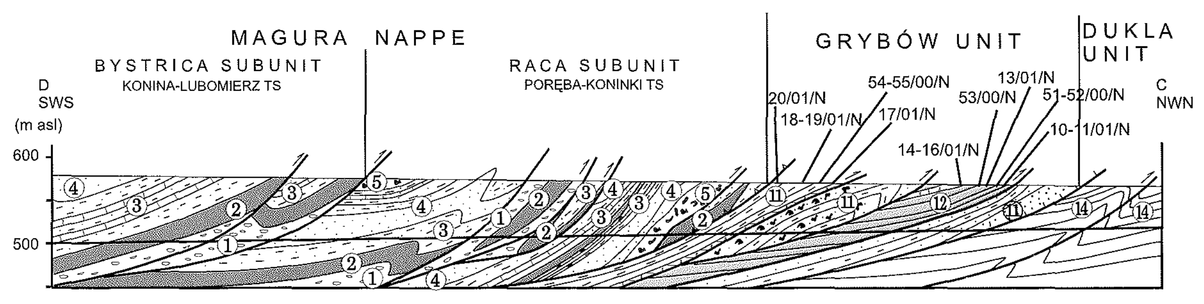


Fig. 5. Geological cross-section through the southern margin of the Mszana Dolna tectonic window, along the Koninka stream (For explanation see Text-fig. 4)

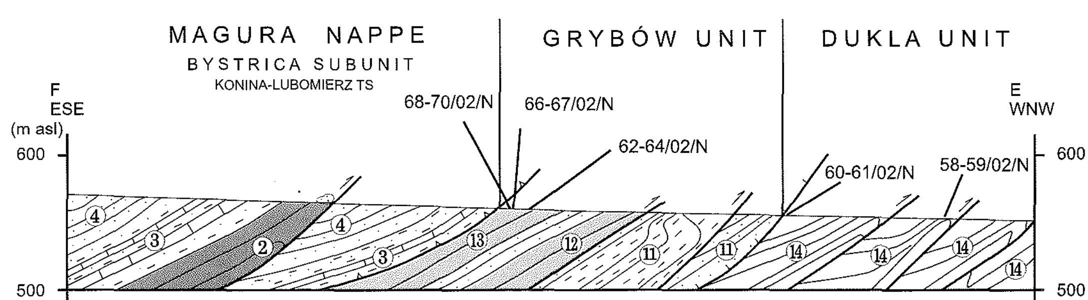


Fig. 6. Geological cross-section through the southern margin of the Mszana Dolna tectonic window, along the Mszanka stream (For explanation see Text-fig. 4)

member is composed of a few metres of green-grey non-calcareous shales (Text-fig. 7). The middle part of the sequence is dominated by dark-grey mudstone/siltstone couplets and very fine, thin-bedded muscovite sandstones. The upper part of this sequence is composed of thin- to medium-bedded sandstones, intercalated by dark grey silt/shelly couplets, green/yellowish if weathered. The yellowish siltstones are often calcareous and strongly bioturbated (Helminthoida facies see CIESZKOWSKI & *al.* 1989). In the Poręba Górna section

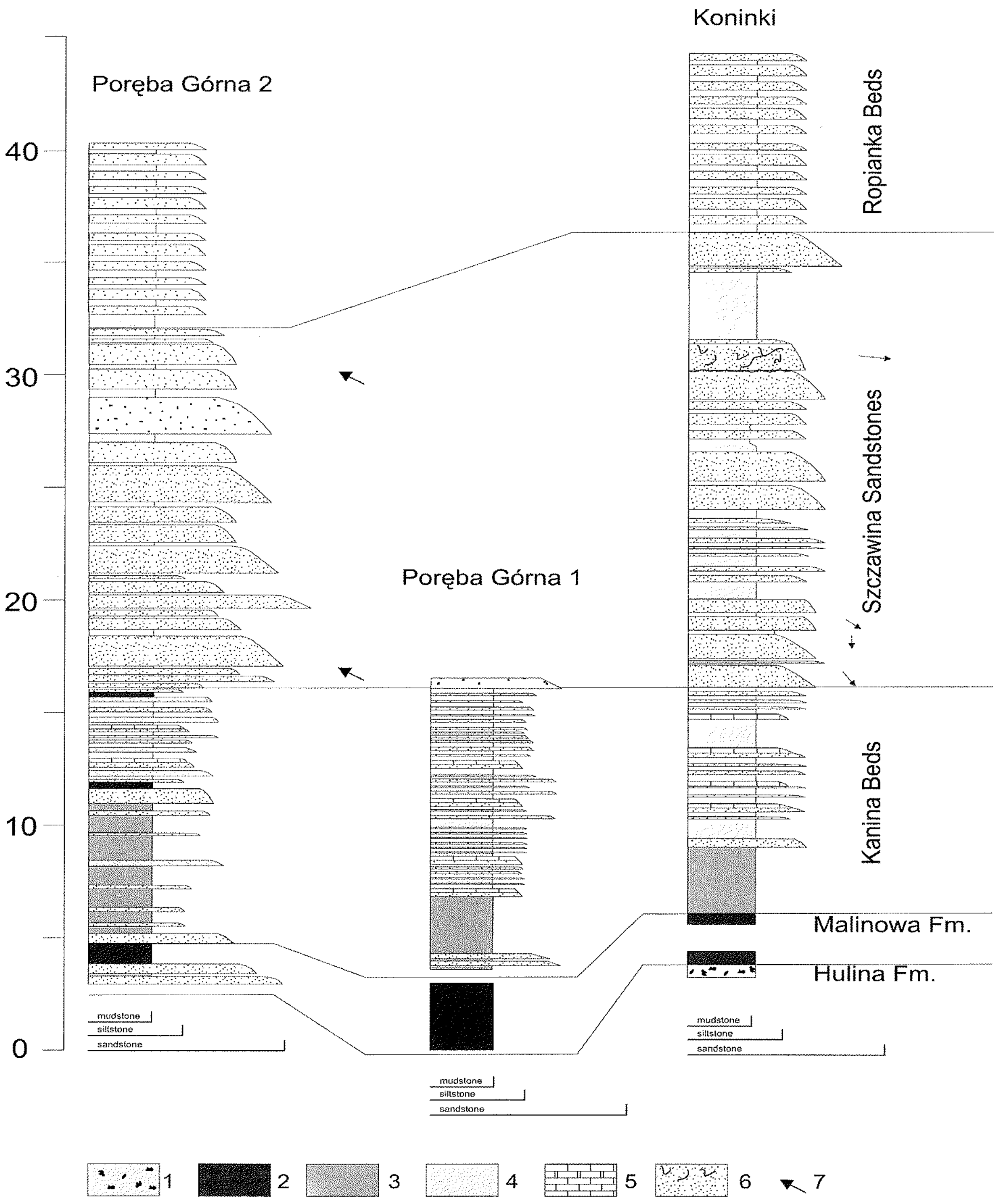


Fig. 7. Lithostratigraphic logs of Cretaceous-Palaeocene of the Koninki-Poręba Gorna thrust sheet (Rača Subunit); 1 – spotty shles, 2 – red shales, 3 – green shales, 4 – grey shales, 5 – turbidite limestones, 6 – slurry structure, 7 – palaeotrasport direction

the Kanina Beds, with a few thin intercalations of red shales, resemble the Hałuszowa Formation (see BIRKENMAJER & OSZCZYPKO 1989) from the Zasadne section (MALATA & OSZCZYPKO 1990). The lower member contains intercalations of turbidite limestones (CIESZKOWSKI & *al.* 1989). In the Poręba Górna section (PKTS) frequent intercalations of turbidite limestones have been observed in the upper part of the Beds (ca 12-15 cm thick). The thickness of the lower member varies from around 10 m in Poręba-Koninki to around 50 m in the Konina-Lubomierz thrust-sheets (Text-figs 7-8, see also OSZCZYPKO & *al.* 1999b). It reveals a coarsening- and thickening-upward sequence, and contains heavy zircone-tourmaline-rutile minerals, sometimes with chromite spinels (Lubomierz section, see SALATA 2003) displaying palaeotransport from the SE. The age of the lower member, based on foraminiferal studies, is early-middle Campanian (BĄK & OSZCZYPKO 2000, MALATA 2001).

The middle member (=Szczawina Sandstones): The Kanina Beds are followed by thick-bedded sandstones and granule conglomerates, commonly known as the Szczawina Sandstones. In the Poręba Górna section these sandstones, up to 20 m thick, reveal important sedimentological differences between the Koninki and Poręba Górna sections (Text-fig. 7). In the Koninki section the beds are represented by 5-8 m thick, fining and thinning upward sequences. The lower part of the sequence (3-4 m thick) is composed of thick-bedded sandstones (0.50-1.5 m), very coarse to medium-grained, sometimes amalgamated with T_{ab} intervals. In this section the thick-bedded sandstones (partly glauconitic) reveal some similarities to the thick-bedded sandstones of the Jaworzynka Beds in the Grybów Unit, and display palaeotransport from the NW and from the SE. In the Poręba Górna section (Text-fig. 7) the Szczawina Sandstones are dominated by thick and very thick-bedded (0.4-2.5 m), medium- to very coarse-grained sandstones with weak carbonate cement. The basal part of the beds is composed of light-coloured quartz-glauconitic, coarse-grained sandstones. At the top of the beds occur grey, calcareous sandstones and mudstones, rich in flakes of muscovite and coalified plants. The muscovite sandstones display palaeotransport from the SE.

In all of the studied sections of the Konina-Lubomierz thrust sheets the thickness of the Szczawina Sandstones reached 100 (125) metres (Text-fig. 8). These sections are dominated by thick-bedded muscovitic sandstones, which display palaeotransport from

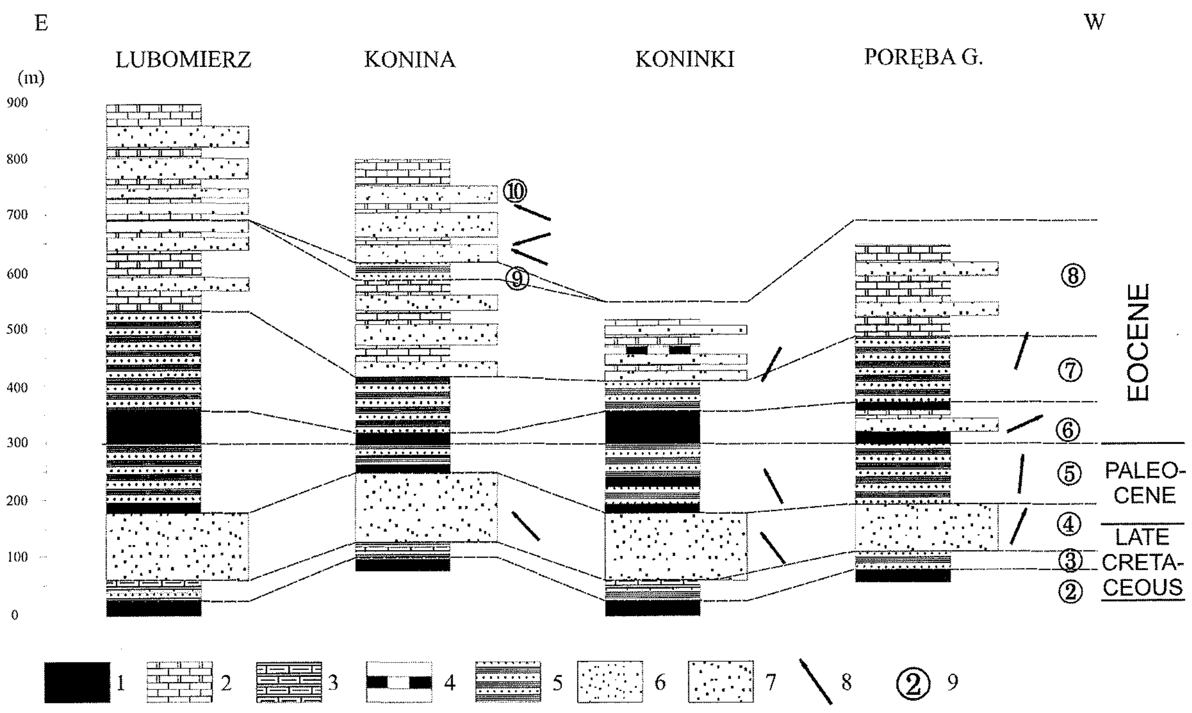


Fig. 8. Lithostratigraphic section of the Konina-Lubomierz thrust sheet (Bystrica Subunit of Magura Nappe), after OSZCZYPKO & *al.* (1999b); 1 – red shales, 2 – turbidite limestones, 3 – turbidite marls, 4 – hornstones, 5 – thin-to medium-bedded turbidites, 6 – thick-bedded turbidites, 7 – thick bedded sandstones and conglomerates, 8 – palaeotransport direction, 9 – litostratigraphic units: 2 – Malinowa Shale Formation and Hałuszowa Formation, 3 – Kanina Beds, 4 – Szczawina Sandstones, 5 – Ropianka Beds, 6 – Łabowa Shale Formation, 7 – Beloveza Formation, 8 – Bystrica Formation, 9 – Żeleźnikowa Formation, 10 – Maszkowice Member of the Magura Formation

the S and SE and contain heavy zircone-tourmaline-rutile minerals (SALATA 2003). The Szczawina Sandstones are of the ?Maastrichtian-Palaeocene age (see OSZCZYPKO 1992, MALATA & *al.* 1996, MALATA 2001).

The upper member: The uppermost member of the "Inoceramian Beds" belongs to the Ropianka Beds (Palaeocene) and is composed of fining- and an thinning-upward sequence of thin-bedded turbidites with a few thin intercalations of variegated shales. Their thickness varies between 50 and 80 metres (Text-fig. 8). The flute casts reveal palaeotransport from the SE, and contain the heavy zircone-tourmaline-rutile minerals (SALATA 2003).

According to BURTAN & *al.* (1976, 1978) the northern slopes of the Gorce Range are composed of the Eocene deposits of the Bystrica Subunit (Szumiąca-Frączkowa-Lubomierz thrust sheet). However, the results of OSZCZYPKO & *al.* (1999b) documented the presence of two sequences, approximately of the same age: Konina-Lubomierz (N) and Tobołów-Turbaczyk (S). In this paper only the Konina-Lubomierz sequence will be discussed.

Łabowa Shale Formation

Deposits belonging to the Łabowa Shale Formation of the Palaeocene-Lower Eocene age (see OSZCZYPKO 1991, OSZCZYPKO & *al.* 1999b) occur in a narrow belt between Olszówka and Lubomierz (Text-fig. 3). The lowermost portion of the formation is represented by a few metres of red shales passing upwards into very fine-bedded turbidites. Very fine-grained, green, carbonate-free sandstones (T_c) pass upwards into green shales, and finally to a few cm of red shales, mainly soft and free of carbonate. In the Poręba Górna section the lowermost part of this formation contains one or two layers of thick-bedded sandstones (up to 2 m) and intercalations of grey marls. The thickest sandstone bed reveals palaeotransport from ESE. The thickness of the formation attains up to 50 m.

Beloveza Formation

This formation is dominated by thin- to medium-bedded turbidites ($T_{c+conv.}$ and T_{cd}). The vari-coloured shales distinctly prevail over sandstones. The yellowish and brown shales are usually calcareous, while the green ones are, as a rule, carbonate-free. The accompanying medium-bedded T_{bc} sandstones (20-40 cm) appear less frequently. The thickness of the Early-Middle Eocene Beloveza Formation (OSZCZYPKO & *al.* 1999b) reaches 50 to 120 m (Text-fig. 8).

Bystrica Formation

This Middle Eocene formation (OSZCZYPKO 1991, OSZCZYPKO & *al.* 1999b) is well seen in morphology, forming W-E trending round-off hills. It is composed of thick-bedded sandstones with intercalations of Łącko marls. The sandstones, 80-200 cm thick, are massive, medium to coarse-grained, glauconite/muscovite with cement free of carbonate. The flute-casts reveal palaeotransport from the SW. The sandstone layers pass into massive marls, sometimes silicified, brown or blue-to-grey and whitish, when weathered. The thickness of the individual beds of the Łącko marls ranges from 2 to 5 m. In the Koninki section (Text-figs 3, 8) the marls contain 1-20 cm intercalations of black hornstones. The thickness of the formation is up to 150 m (Text-fig. 8).

Żeleźnikowa Formation

The equivalents of the Middle Eocene Żeleźnikowa Formation (see OSZCZYPKO 1991, OSZCZYPKO & *al.* 1999b) have been found in a few stream sections east of the Koninki stream. As a rule, these deposits occur between the Bystrica Formation and the Maszkowice Member of the Magura Formation. They are composed of the thin- to medium-bedded turbidites of the Beloveza lithofacies with numerous intercalations of Łącko marls. The thickness of the formation is up to 50 metres (Text-fig. 8).

Magura Formation - Maszkowice Member

The Middle Eocene Maszkowice Member (see OSZCZYPKO 1991, OSZCZYPKO & *al.* 1999b) is exposed exclusively in the Lubomierz and Konina sections (Text-figs 2-3, 8). This member is represented by thick and medium-bedded muscovite sandstones with infrequent intercalations of Łącko marls. The sandstones are 0.4-2.0 m thick, medium- to coarse-grained, muscovite with illite-carbonate cement. They are massive, sometimes amalgamated and often contain muddy intraclasts and coalified flakes in the upper portion of the member. The intercalations of the Łącko marls range from 0.8 to 2.0 m in thickness. The marls are greyish and whitish if weathered. In the Konina section thick-bedded sandstones and marls are followed by a 60-100 m sequence of thin- to medium-bedded sandstone/marly turbidites. The tectonically reduced thickness of the Maszkowice Member is up to 200 m. The flute casts reveal palaeotransport from the SE (Text-fig. 8).

Grybów Unit

The Grybów Unit of the MDW occurs as an erosional outliers at the top of the elevated part of the

Dukla Unit as well as a narrow thrust sheet edged between the Dukla and Magura units along the southern margin of the tectonic window. The tectonically reduced succession of the Grybów Unit of the MDW is composed of the Lower Cretaceous to Oligocene deposits. According to BURTAN & *al.* (1976, 1978, 1992a) the Grybów unit is composed of the following strata: Lgota Beds (Albian-Cenomanian), Inoceramian (Cisna) Beds (Senonian), Jaworzynka Beds (Senonian-Palaeocene), black shales with siderites (Palaeocene), variegated and green shales (Eocene), dark shales and glauconitic sandstones ("black Eocene", see BURTAN & al. 1992a); Łużna-Koniaków limestones (Eocene), Menilite shales with thick-bedded sandstones at the top (Oligocene), and Krosno Beds-shales (Oligocene), known also as Cergowa Beds (BURTAN & *al.* 1992a). Majority of these divisions are known only from the synclinal erosional outlier near Podobin (Text-fig. 3), though their ages were assumed based only on lithological analogies. On the geological map (BURTAN & *al.* 1976) the majority of the geological boundaries display a tectonic character. According to BURTAN & *al.* (1992a) the total thickness of the Grybów Unit reached around 1500 m. In the studied sections (Poręba Wielka, Koninki, Domagałowy streams, Konina and Lubomierz) the total thickness of the Grybów Unit is a few times smaller. This concurs with MASTELLA (1988) in so far that, in these areas, we could only determine two lithostratigraphic units.

Jaworzynka Beds

In the Koninki, Poręba Górna and Lubomierz sections (Text-figs 3, 9) the basal part of the Grybów Unit is composed of the Jaworzynka Beds, represented by 30-50 m thick packets of fine conglomerates and thick-bedded, biotite-feldspar sandstones, with intercalations of

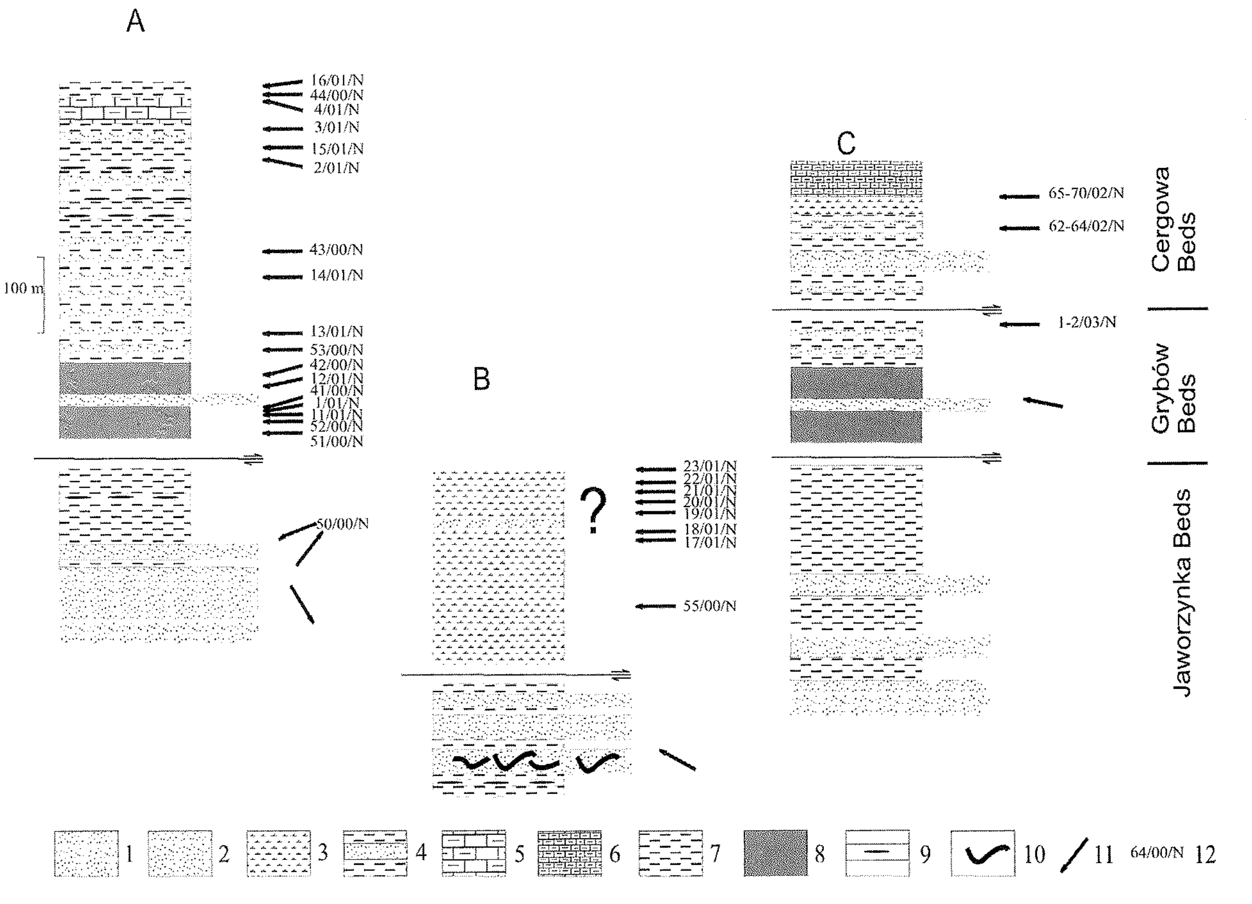


Fig. 9. Litostratigraphic logs of the Grybów Unit in the Mszana Dolna tectonic window; 1 – thick-bedded, feldspare-glauconite sandstones, 2 – thick-bedded, muscovite sandstones, 3 – marly claystones and mudstones with intercalations of very thin- bedded sandstones, 4 – dark-gray laminated marly mudstones and black shales with intercalation of very thin-bedded sandstones, 5 – dark-gray massive marls, 6 – laminated marls, 7 – dark-grey non-calcareous mudstones, 8 – black and brown Menilite type shales, 9 – siderites, 10 – sub-marine slump, 11 – paleocurrent dirrection, 12 – samples localites

dark, non-calcareous mudstones and siltstones. In the Koninki section these Beds contain Palaeocene foraminifers (E. MALATA, personal information, 2002). The sandstones reveal palaeotransport from the NW, and contain heavy zircone-tourmaline-rutile minerals (SALATA 2003). Higher up in the sections occur strongly deformed dark shales and micaceous mudstones (Text-fig. 10A) with intercalations of thin- to thick-bedded, muscovite sandstones and sporadic intercalations of siderites. This part of the sequence probably can be correlated with "Palaeocene shales and sandstones with siderites" (see BURTAN & *al.* 1992a).

The second thrust-sheet of the Koninki section is composed probably exclusively of the Palaeocene deposits. The lower part of the thrust-sheet is represented by imbricated folds composed of thick-bedded,

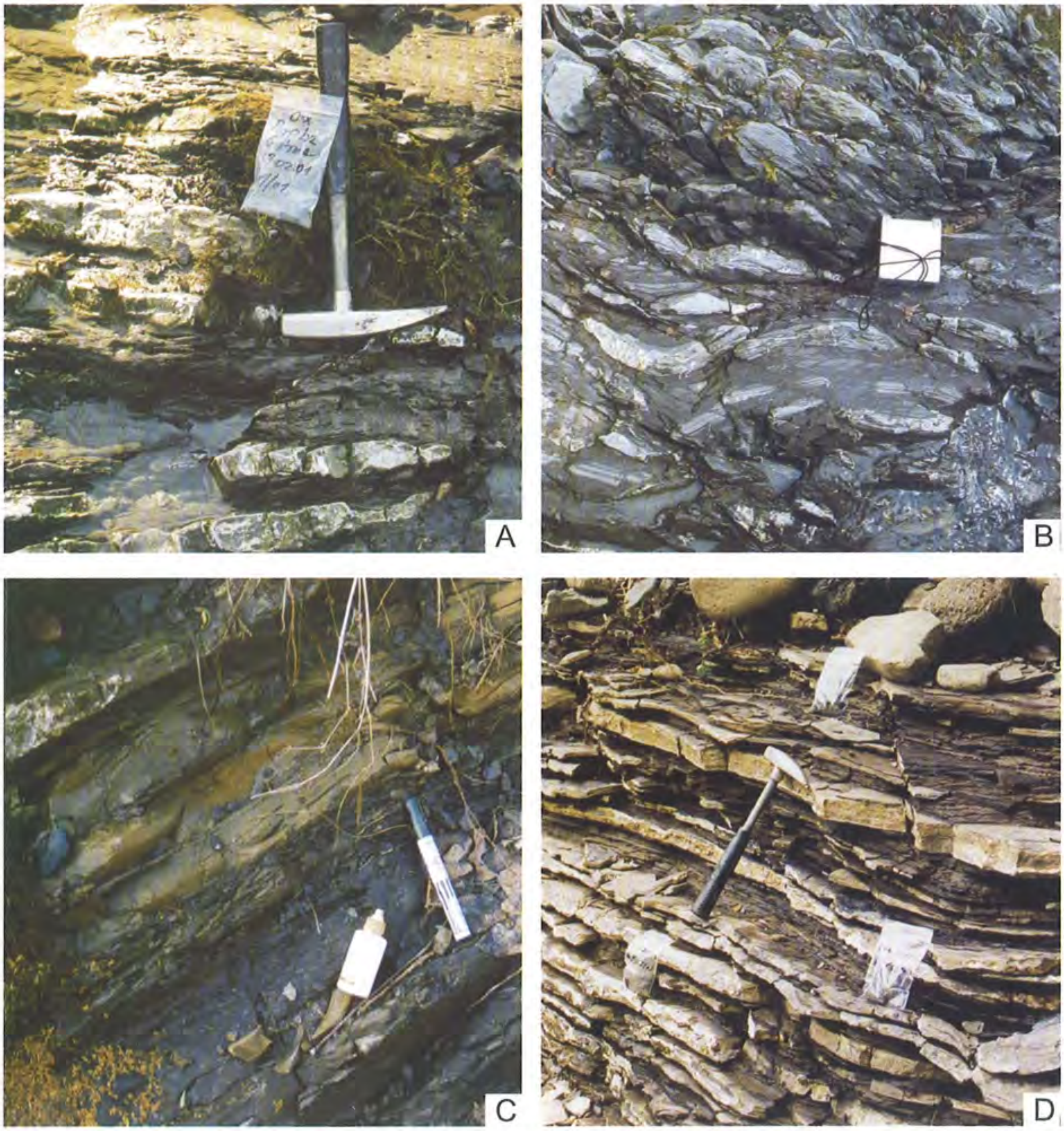


Fig. 10. A – Black shales with intercalations of thin-bedded, very fine-grained sandstones (Tc turbidite) of the lower part of the Grybów Beds (Oligocene). Grybow Unit - Poręba Górna stream (see Text-fig. 4); B – Strongly tectonized dark grey marly shales with intercalations of thin-bedded, calcareous sandstones of the upper part of Grybów Beds (Oligocene). Grybów Unit-Koninki stream (see Text-fig. 5); C – Dark calcareous mudstones with intercalations of thin-bedded, calcareous sandstones of the upper part of the Grybów Beds (Oligocene). Poręba Górna stream (see Text-fig. 4); D – Very fine, thin-bedded calcareous sandstones of the the Cergowa Beds (Late Oligocene). Grybów Unit, Mszanka stream at Lubomierz (Text-fig. 6).

coarse-grained sandstones and rich in muscovite flakes. The sandstones are intercalated with black, non-calcareous shales with a siderite layer. The sandstones are followed by black, poorly calcareous shales with sporadic intercalations of very thin-bedded sandstones and siltstones. According to BURTAN & *al.* (1976, 1978) these shales belong to shaley facies of the Krosno Beds (Oligocene). Unfortunately, numerous samples taken by authors for nannofossil investigations from these Beds were sterile (Text-figs 5, 9). Since Palaeocene foraminifers were determined two hundred metres higher up in the section (E. MALATA personal inf., 2002) in the same beds beneath the Poręba-Koninki TS of the Magura Nappe (Text-figs 5, 9). In our opinion "Shaley facies of the Krosno" belong to the Jaworzynka Beds of the Grybów succession.

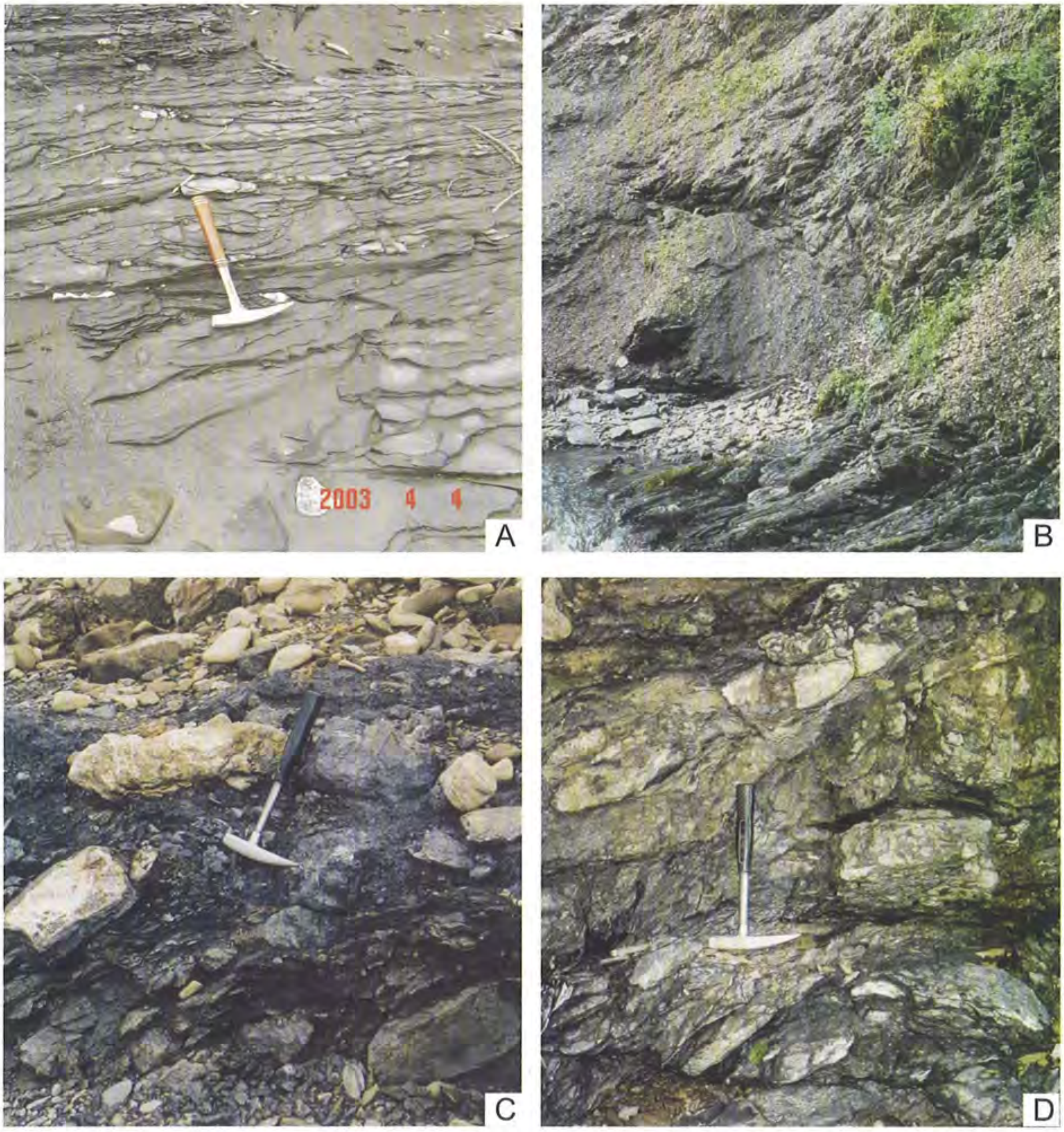


Fig. 11. A – Dark grey, marly shales of the uppermost part of the Krosno Beds (Oligocene) of the Dukla Unit. Konina stream (Text-fig. 3); B – Left bank of the Koninki stream (150 m below the Grybów thrust) - shally facies of the Krosno Beds (Oligocene) of the Dukla Unit (Text-fig. 3); C – Base of the Magura thrust-breccia of the ? Kanina Beds (Campanian). Koninki stream (Text-fig. 4); D – Chaotic deposits (Upper Cretaceous) in the basal part of the Magura Nappe (Poręba Beds-tectonic melange, see BURTAN & ŁYDKA 1978, BURTAN & *al.* 1978). Poręba stream around 15 m above the Magura thrust (Text-fig. 4)

Grybów Beds

In the Koninki section the Jaworzynka Beds are bounded tectonically by a repetition of dark and grey, laminated, marly mudstones, intercalated by thin- and medium- bedded, fine-grained, calcareous sandstones and thin-bedded siderites of the Grybów Beds (Text-fig. 10B). In the Poręba Górna section the lower portion of the Grybów Beds are developed as black, non calcareous shales with intercalations of thinl-bedded sandstones with a SW dipping block of massive, muscovite sandstone of the Cergowa type. Higher up in the section, the upper portion of the Grybów Beds are represented by black shales and marly mudstones with intercalations of thin-bedded sandstones and thick-bedded dark, calcareous mudstones (Text-fig. 10C) with siderite nodules (Text-figs 4-5, 9). In the Lubomierz section deposits of the Jaworzynka Beds type are tectonically bounded by a 50 m thick succession of dark grey, calcareous, muscovite mudstones with intercalations of very thin-bedded sandstones. Subordinately, thick-bedded sandstones are also observed (Text-fig. 6). These are massive, muscovite-glauconitic sandstones, up to 2 m thick and are very coarse to coarse. The uppermost part of the section is dominated by dark-grey marls with intercalations of very fine, thin-bedded, parallel laminated, muscovite sandstones (Text-fig. 10D). These deposits resemble the Cergowa Beds from the Szczawa section.

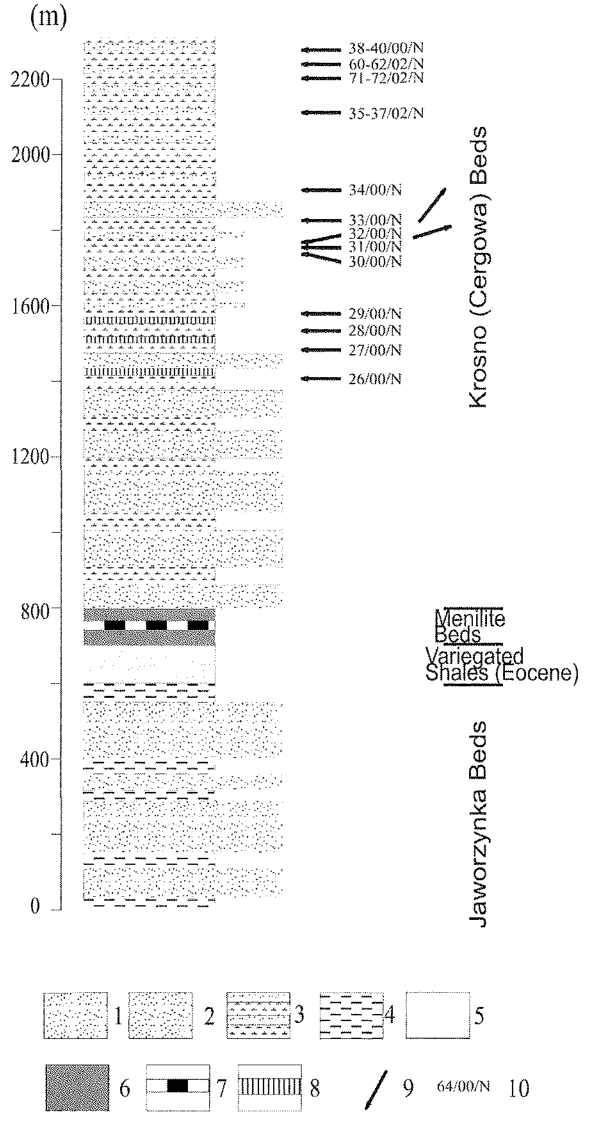


Fig. 12. Lithostratigraphic log of Dukla Unit in Mszana Dolna tectonic window (based on BURTAN & *al.* 1978, supplemented); 1 – thick-bedded, feldspare-glauconite sandstones, 2 – thick-bedded, muscovite sandstones, 3 – grey, marly claystones and mudstones with intercalations of very thin- bedded sandstones, 4 – dark-grey non calcareous mudstones, 5 – variegated shales, 6 – black shales, 7 – hornstones, 8 – siderites, 9 – paleocurrent direction, 10 – location of samples

Dukla (Obidowa – Słopnice) Unit

The oldest Cretaceous-Palaeocene and Eocene deposits of the Dukla Unit are known exclusively from the boreholes (Text-figs 3, 12-13): Poręba W-1, Poręba W-IG1 (BURTAN & *al.* 1978) and Niedźwiedź-1 (POŁTOWICZ 1985). According to BURTAN & *al.* (1992a, b) these deposits are represented by: the Senonian-Palaeocene Jaworzynka Beds ("Inoceramian" Beds in the biotite facies), variegated shales (Palaeocene-Middle Eocene), Hieroglyphic Beds (Middle/Upper Eocene), "Black Upper Eocene" and Menilite (Grybów) Beds with hornstone intercalations (Oligocene).

Krosno Beds

The Oligocene Krosno Beds are well known from the surface exposures (Text-fig. 3). These deposits generally dip towards the SE. The lower part of this formation is composed of grey, fine- to medium-grained, medium- to thick-bedded (up to 1. 5 m), calcareous sandstones of the Cergowa type with intercalations of dark-grey, marly shales and subordinate siderites (8-12 cm thick). The medium-bedded sandstones display mainly T_{bc} Bouma intervals and palaeotransport from WSW (exposures are observable in the cliff, on the left bank of the Mszanka stream in the northern part of the village of Niedźwiedź). The most frequent lithofacies of the Krosno Beds are represented by thin- to medium-bedded turbidites. The upper portion of the Krosno Beds, at least 450 m thick, belongs to dark-grey marly mudstones with sporadic intercalations of thin- to medium-bedded, muscovite, calcareous sandstones (Text-fig. 11A, B). The base of the Krosno Beds was reached at depths between 1355 and 1591 m in the Niedźwiedź 1 and Poręba Wielka IG-1 boreholes, respectively (Text-figs 2, 13). The total thickness of these Beds in MDW is at least 2000 m. The base of the Dukla Unit was pierced in the Niedźwiedź 1 borehole at 2790 m, which terminated at a depth of 4478.3 m in the Upper Cretaceous–Palaeocene flysch deposits, which probably belonged to the Silesian Unit (Text-fig. 13).

Structure of the southern margin of the Mszana Dolna tectonic window

The studied area is located in the middle part of the Magura Nappe on the southern margin of the MDW and about 15 km south of the front of the nappe (Text-fig. 2). The Magura Nappe is very flatly overthrust onto the Oligocene Krosno Beds of MDW (see BURTAN & *al.* 1978, MASTELLA 1988).

The relationships between the Dukla, Grybów and Magura units can be observed along the southern margin of the MDW. The best contact exposures are located in the Poręba Górna, Koninki and Lubomierz sections (Text-figs 4-6). In these sections (100-300 m in length) one or two thrust-sheets of the Grybów Unit are edged between the Dukla and Magura units. The Grybów Unit is separated by the two moderately inclined or sub-horizontal, south deepening thrust surfaces.

In the Koninki stream the uppermost part of the Dukla sequence is composed of the Krosno Beds shaly facies. Towards the south the beds reveal an increasing degree of tectonic deformation (Text-fig. 11B) of mesoscopic, thrust-fault propagating folds to a few meter thick breccia zone of shales with sandstone lamps. In this section the Grybów Unit is built up of two thrust-sheets composed of the Jaworzynka Beds (Palaeocene) and the Grybów Beds (Oligocene, see Text-fig. 11B). The contact of the Grybów and Magura units is marked by a zone of strongly brecciated rocks (Text-fig. 11 C).

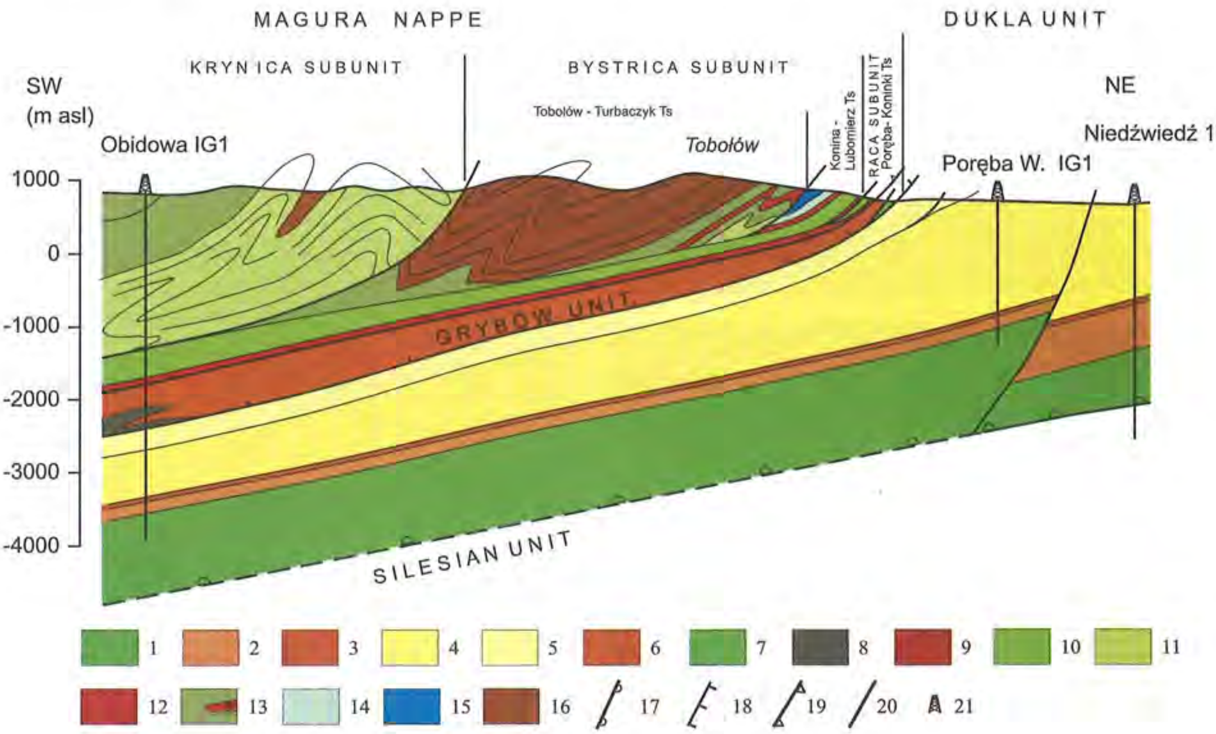


Fig. 13. Geological cross-section Obidowa IG 1 – Niedźwiedź 1 boreholes (based on Polish Geological Survey maps (BURTAN & *al.* 1976, CIESZKOWSKI 1985, POŁTOWICZ 1985); Dukla Unit: 1 – Upper Cretaceous-Palaeocene, 2 – sub-menilite Eocene, 3 – Menilite Beds (Oligocene); Krosno Beds (Oligocene): 4 – thick-bedded sandstones and sandstone-shaley facies, 5 – shaley facies; Grybów Unit: 6 – Grybów Unit undivided, 7 – Jaworzynka Beds, 8 – Black Eocene; Magura Nappe: 9 – Albian-Cenomanian deposits and Malinowa Shale Formation (Turonian Santonian), 10 – Campanian-Palaeocene (Kanina, Szczawina and Ropianka Beds); 11 – Szczawnica Formation (Palaeocene-Lower Eocene), Eocene: 12 – Łabowa Formation, 13 – Zarzecze Formation, a – variegated shales, 14 – Beloveza Formation, 15 – Bystrica and Żeleźnikowa formations, 16 – Magura Formation, 17 – Dukla overthrust, 18 – Grybów overthrust, 19 – Magura overthrust, 20 – faults, 21 – boreholes

In the lower course (Text-figs 3-4) of the Poręba Górna stream section, the basal portion of the Grybów Unit begins with blocks of the Jaworzynka Beds (Palaeocene), passing upwards into the Grybów Beds, which display numerous NWN-SES to N-S trending, mesoscopic, sub-vertical thrust-fault propagating folds. The southerly deepening Dukla and Grybów units have been found beneath the Magura Nappe, in the Obidowa IG-1 borehole (Text-fig. 13, see also CIESZKOWSKI 1985).

Between Olszówka and Lubomierz the frontal part of the Magura Nappe consists of three thrust-sheets which contain characteristic sequences of deposits (OSZCZYPKO & *al.* 1999b). From the north to the south these are: Poręba Wielka-Koninki (Albian-Palaeocene), Konina-Lubomierz (Turonian-Middle Eocene) and Tobołów-Turbaczyk (Lower-Middle/?Upper Eocene) thrust-sheets (Text-figs 3, 11). The lower, Poręba Wielka-Koninki thrust-sheet belongs probably to the Rača Subunit. The basal portion of the Poręba Wielka-Koninki thrust-sheet reveals a complex of chaotic type "melange" deformation (Text-figs 4-5), described by BURTAN & ŁYDKA (1978,

Fig. 14. A – The chaotic deposits of the Poręba Beds with two-type of boundaries; fluidal-and shear fracture plane boundaries. Poręba Górna stream-around 20 m above the Magura thrust (Text-fig. 4); B – The upper "stratified" part of the Poręba Beds. Poręba Górna stream - around 40 m above the Magura thrust (Text-fig. 4); C – Recumbed fold of the upper part of the Malinowa Formation (Turonian-Santonian) of the Poręba-Koninki thrust-sheet. Poręba Górna stream (Text-fig. 4); D – The right bank of the Mszanka stream at Lubomierz. The Kanina Beds (Campanian) of the Konina-Lubomierz thrust sheet

see also BURTAN & *al.* 1978) as the Poręba Wielka Beds ("wild flysch").

In the Poręba Wielka section the Magura Nappe (Poręba-Koninki thrust-sheet) begins with a SW dipping (inclination is around 30°) sole trust, composed of a 3 m thick packet of medium-bedded sandstones and grey-greenish shales. This stratified unit is covered by a 40-50 m thick complex of chaotic deposits (Text-fig. 11D; Text-fig. 14A), known as the Poręba Wielka Beds of the Turonian-Senonian age (see BURTAN & *al.* 1978). These deposits contain fragments of blue-greyish, medium-grained non-calcareous sandstones of various size (from 1 cm to 1.5 m boulders) and shape, which are dispersed in a green-greyish and dark-greyish, non-calcareous, clay-claystone matrix. Among sandstone fragments, small lumps of drag-folds have been observed. The sandstone fragments show primary fractures, often with calcite mineralization. The sandstone blocks and shales sometimes reveal the remnants of primary stratification (Text-fig. 14B). The chaotic deposits occur in layers ranging from a few cm up to 0.5 m thick, with two types of boundaries; fluidal- and shear fracture plane boundaries. The shear plane-type boundaries are accompanied by calcite veins. Both types of boundaries are gently dipping and are almost parallel to each other towards the NE and SW in the basal and top part of the chaotic body, respectively. These sub-horizontal planes are cut occasionally by W-E trending sub-vertical, south dipping inverse faults with calcite mineralization. The lower, strongly chaotic part is covered by the upper, less chaotic part with a more frequent, primary type of stratification. Towards the top of this unit, random-dispersed sandstone fragments are progressively replaced by boudin-like fragments.

The Poręba Wielka Beds are tectonically followed upward by the 50 m thick unit, characterized by an occurrence at outcrop scale, NWN-SES trending recumbed and imbricated folds (Text-fig. 14C) of the Malinowa Formation (Turonian-Santonian) and Kanina Beds (Campanian). This unit passes into the steep, south-west dipping, thin-bedded flysch of the Kanina Beds and thick-bedded Szczawina Sandstones (Maastrichtian-Palaeocene). The sandstones reveal a brittle-typed deformation, with numerous small-scale W-E and WNW-ESE trendings, and S-SWS dipping inverse faults. The Szczawina sandstones are followed by strongly tectonized Ropianka Beds (Palaeocene) with a degree of deformation the same as that from the Poręba Beds. The Ropianka Beds are overthrust by the Malinowa Shale Formation (Turonian-Santonian) and compose a basal portion of the Bystrica Subunit sequence.

The front of the Bystrica Subunit is built up of the next Konina-Lubomierz thrust sheet, which is 1.5-2 km wide and forms a moderately south-dipping homocline (Text-figs 2-6; Text-fig. 14D). Along this thrust, numerous mesoscopic WNW-ESE and NW-SE trending folds have been observed. At the boundary between the complexes with different competence, inverse faults, parallel to the frontal thrust, have been documented (OSZCZYPKO & *al.* 1999b). These caused a reduction in the thickness of the Łabowa and Beloveza formations. The Tobołów-Turbaczyk thrust sheet of the Bystrica Subunit is characterized by the strongly deformed Zarzecze Formation and south-dipping Magura Formation. The Tobołów-Turbaczyk thrust sheet is overthrust by the Krynica Subunit, composed of Palaeocene-Eocene deposits of the Szczawnica, Zarzecze and Magura formations (see OSZCZYPKO & *al.* 1999b). All of these Magura Nappe subunits have been pierced in the Obidowa IG-1 borehole, which is located 15 km SW from the margin of the Mszana Dolna tectonic window (Text-fig. 13).

SZCZAWA TECTONIC WINDOW

The Mszana Dolna and Szczawa tectonic windows belong to the same, most highly elevated zone in the Magura Nappe (Text-fig. 2). The Szczawa tectonic window is situated 15 km SE of the Mszana Dolna, within the NW-SE trending elevation that is bounded by a NW-SW transversal fault (Text-fig. 15). The triangular-shaped, tectonic window (ca. 1.1 sq km) is composed of the Oligocene deposits of the Grybów Unit. The Grybów Unit dips below the Upper Cretaceous–Palaeocene deposits of the Magura Nappe (CHRZĄSTKOWSKI 1971; PAUL 1980, CIESZKOWSKI & *al.* 1987, 1989; OSZCZYPKO & *al.* 1991). The Magura thrust surface dips steeply towards the south but flatly to the west, not exceeding 7° (Text-figs 15-17, see also OSZCZYPKO & *al.* 1991). In the SZCZAWA IV borehole, on the western periphery of the window, the Grybów Unit was pierced at a depth of 97 m in the Kamienica valley.

Magura Nappe

The Szczawa tectonic window is located inside the Bystrica Subunit. On account of this, the stratigraphy of the Bystrica Subunit in the Szczawa and Mszana Dolna areas is generally the same. For this reason, the Turonian-Palaeocene deposits will be described just briefly.

In the studied area, the oldest deposits of the Bystrica Subunit of the Magura Nappe belong to the upper part of the Malinowa Shale Formation (see OSZCZYPKO & *al.* 1991). The lowest part of the formation is known from the Zasadne section, located 3-4

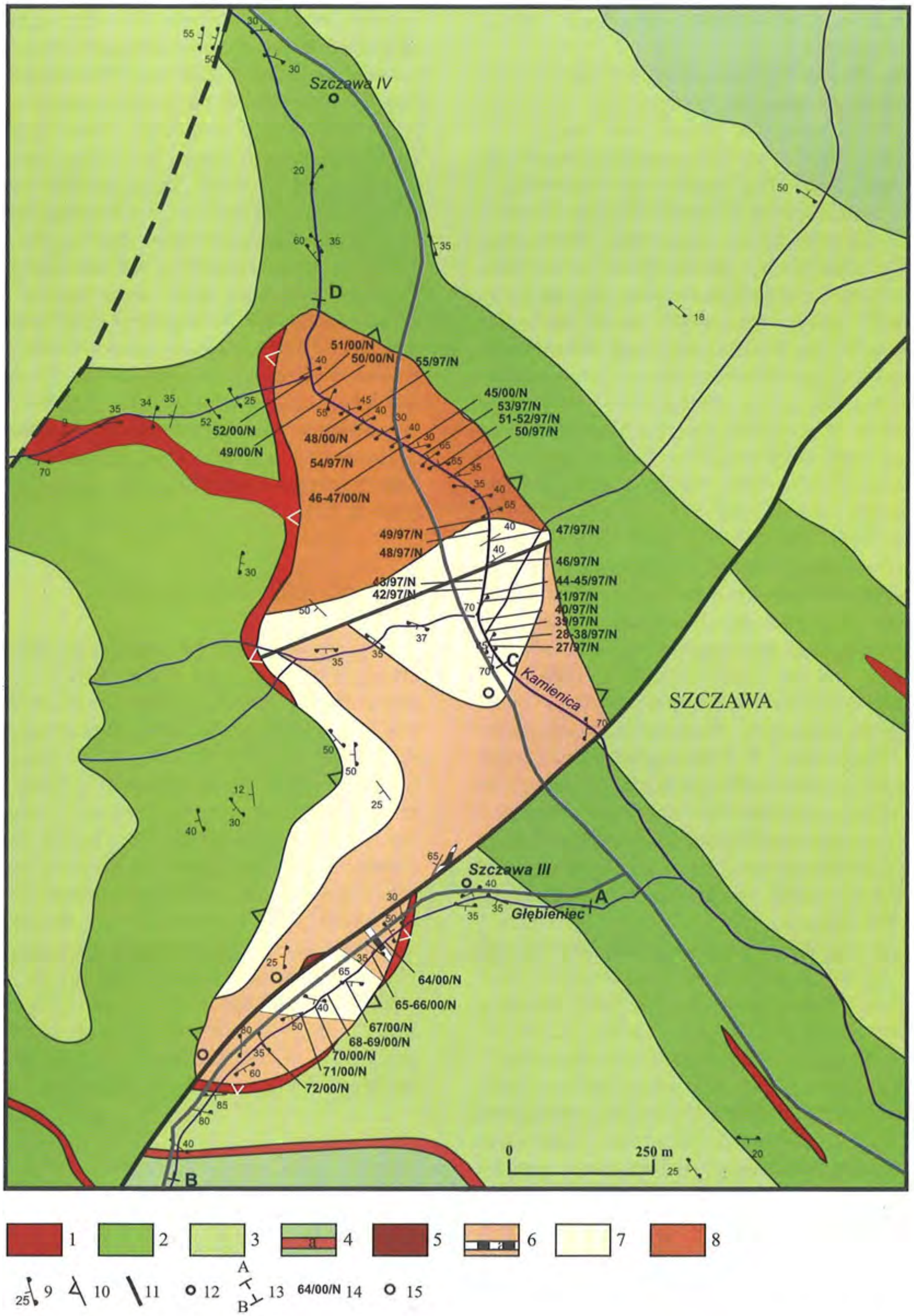


Fig. 15. Geological map of the Szczawa tectonic window; 1 – Magura Nappe: Turonian-Palaeocene 1 – Malinowa Shale Formation (Turonian-Santonian), 2 – Kanina Beds (Campanian), 3 – Szczawina Sandstones (Maastrichtian), 4 – Ropianka Beds (Maastrichtian-Palaeocene), a – varigated shales; Grybów Unit: 5 – Eocene variegated shales; Upper Eocene-Oligocene: 6 – Grybów Beds - black non calacareous shales, a – hornstones, 7 – black and grey marly shales and marls, 8 – Cergowa Beds- grey marls and thick-bedded sandstones, 9 – deep and strike, 10 – overthrust, 11 – faults, 12 – borehole, 13 – cross-section, 14 – samples localites, 15 – mineral springs

km SE of Szczawa. In this section the age of the formation was determined as Late Turonian-Santonian (MALATA & OSZCZYPKO 1990, CIESZKOWSKI & *al.* 1999). This formation is composed of red, non-calcareous shales, which are overlain by graded calcareous marls with red intercalations (Hałuszowa Formation, see MALATA & OSZCZYPKO 1990) or by thin- to medium-bedded flysch deposits of the Kanina Beds (Campanian) with intercalations of turbiditic limestones (CIESZKOWSKI & *al.* 1989). The Hałuszowa Formation contains tourmaline/zircone/apatite/garnet spectrum of heavy minerals (CIESZKOWSKI & *al.* 1999). The Hałuszowa/Kanina Beds, up to 100 m thick, display palaeotransport from the SE and are overlain by thick-bedded, Szczawina Sandstones (Maastrichtian-Palaeocene). The beds are composed of 0.5-4.0 m thick beds, of coarse- to medium-grained, muscovitic sandstones, intercalated by thin mudstone shales (Text-fig. 18A). In the Zasadne section the Szczawina Sandstones are 30 m thick, and display palaeotransport from the SE. The heavy minerals are represented by garnet/apatite/zircon/tourmaline and rutile (CIESZKOWSKI & *al.* 1999). The Szczawina Sandstones, up to 200 m thick are overlain by Ropianka Beds (Palaeocene). These Beds are composed of thin- to medium-bedded calcareous, 100-150 m thick. Higher up in the section occurs a 40-50 m thick series of the Palaeocene-Early Eocene variegated shales of the Łabowa Formation. The beds are overlain by very thin-bedded turbidites, 200-400 m thick, of the Beloveza Formation of the Early-Middle Eocene age and Bystrica Beds (Middle Eocene). The youngest portion of the Bystrica Subunit is represented by a coarsening and thickening upward turbidite sequence with 1-6 m thick intercalations of the Łącko marls (OSZCZYPKO & *al.* 1991). The beds belong to the Bystrica Formation (Middle Eocene) and to the Maszkowice Member (Middle Eocene) of the Magura Formation. These lithostratigraphic units are 150-200 and 350-400 m thick, respectively.

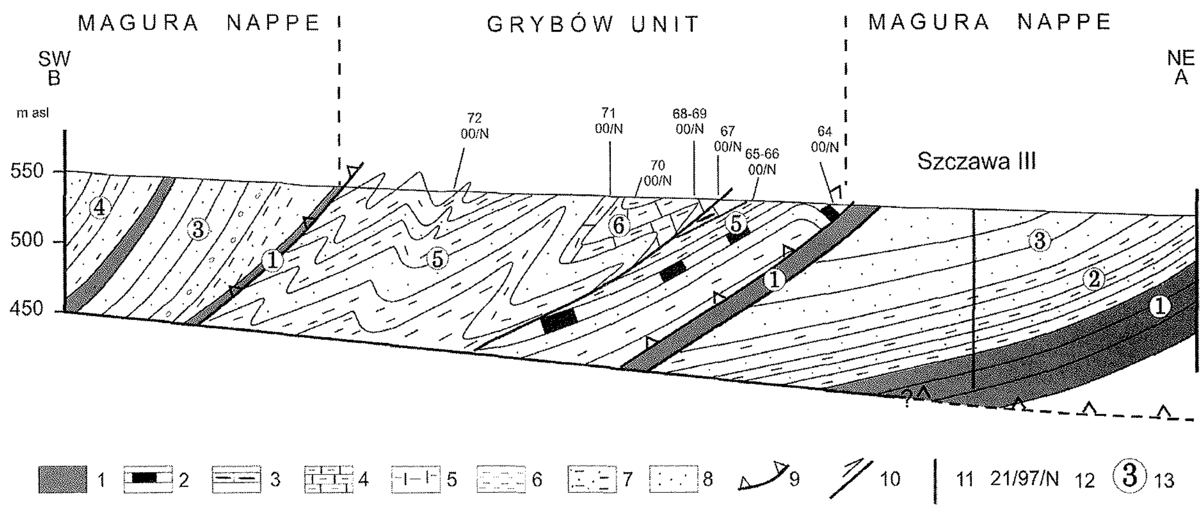


Fig. 16. Geological cross-section along the Głębieniec stream in Szczawa; 1 – variegated shales, 2 – hornstones, 3 – spherosiderites, 4 – black and grey laminated marls, 5 – grey thick-bedded marls, 6 – black non-calcareous sheles, 7 – thin-to medium-bedded turbidites, 8 – thick-bedded sandstones, 9 – Magura overthrust, 10 – fault, 11 – samples, 12 – borehole, 13 – lithostratigraphic units: 1 – Malinowa Shale Formation and Hałuszowa Formation, 2 – Kanina Beds, 3 – Szczawina Sandstones, 4 – Ropianka Beds, 5 – Grybów Beds - black non-calcareous shales, 6 – black marly shales and marls, 7 – Cergowa Beds

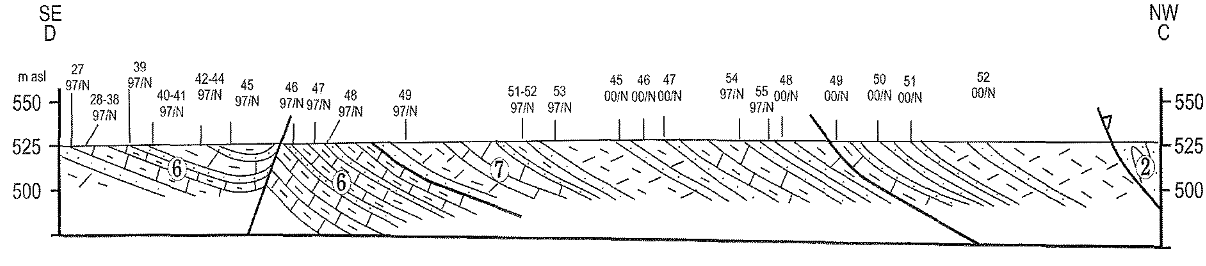


Fig. 17. Geological cross-section along the Kamienica stream in Szczawa. For explanation see Text-fig. 16

Grybów Unit

Grybów Beds

Similarly to the Poręba Górna-Koninki sections, the succession of the Grybów Beds in the Szczawa tectonic window can be subdivided into two members. The basal part of these Beds is exposed in the lower flow of the Głębieniec stream (Text-figs 15-16), and developed as black, sometimes brown, massive, non-calcareous shales, with a few 1-2 cm thick intercalations of black hornstones with a FeS_2 mineralization. Very thin (1-2 cm) layers of hornstones are exposed in the small road-cut on the right slope of the stream. These shales contain sporadic intercalations of fine-grained, glauconitic, thin- to medium-bedded quartzite sandstones (Text-fig. 18 B). The lower mem-

Fig. 18. A – Right bank of the Głębieniec stream in the Szczawa. The basal part of the Magura Nappe composed of medium to thick-bedded turbidites of the Szczawina Sandstones (Maastrichtian - Campanian); B – Rock Beds of the Głębieniec stream in the Szczawa. The lower part of Grybów Beds (Oligocene) - black non-calcareous shales, with thin-bedded quartzitic sandstones; C – The basal portion of the upper part of the Grybów Beds in the Kamienica stream in Szczawa. Thick-bedded sandstones passing upwards into thick-layer of dark calcareous mudstones; D – The upper most part of the Grybów Beds (Oligocene) in the Kamienica stream section at the Szczawa. Dar-grey laminated marls with intercalation of thin-bedded sandstone

ber of the Grybów Beds, at least 60 m thick, passes upward into a sequence of dark mudstones, with siderite lenses and intercalations of thick-bedded, dark-grey marls.

The deposits of the upper member of the Grybów Beds are very well exposed in the Kamienica river (Text-figs 15, 17). The basal part of the member contains intercalations of dark grey, calcareous shales and dark, laminated mudstones with intercalations of very thin-bedded siltstones and very fine-grained sandstones (T_{bcd}, T_{cd} turbidites). Higher up in the section occurs a 75 cm layer of fine- to medium-grained, quartzite sandstones with $T_{abc+conv}$ intervals (Text-fig. 18C). These sandstones pass upwards into dark-brown laminated marls, intercalated by fine-grained, thin-bedded sandstones with cross-ripple lamination (Text-fig. 18D). Higher up in the section occur thick-bedded (up to 2. 5 m) brown and dark, massive or fine-laminated marls, yellowish or rusted if weathered. These turbidite marls

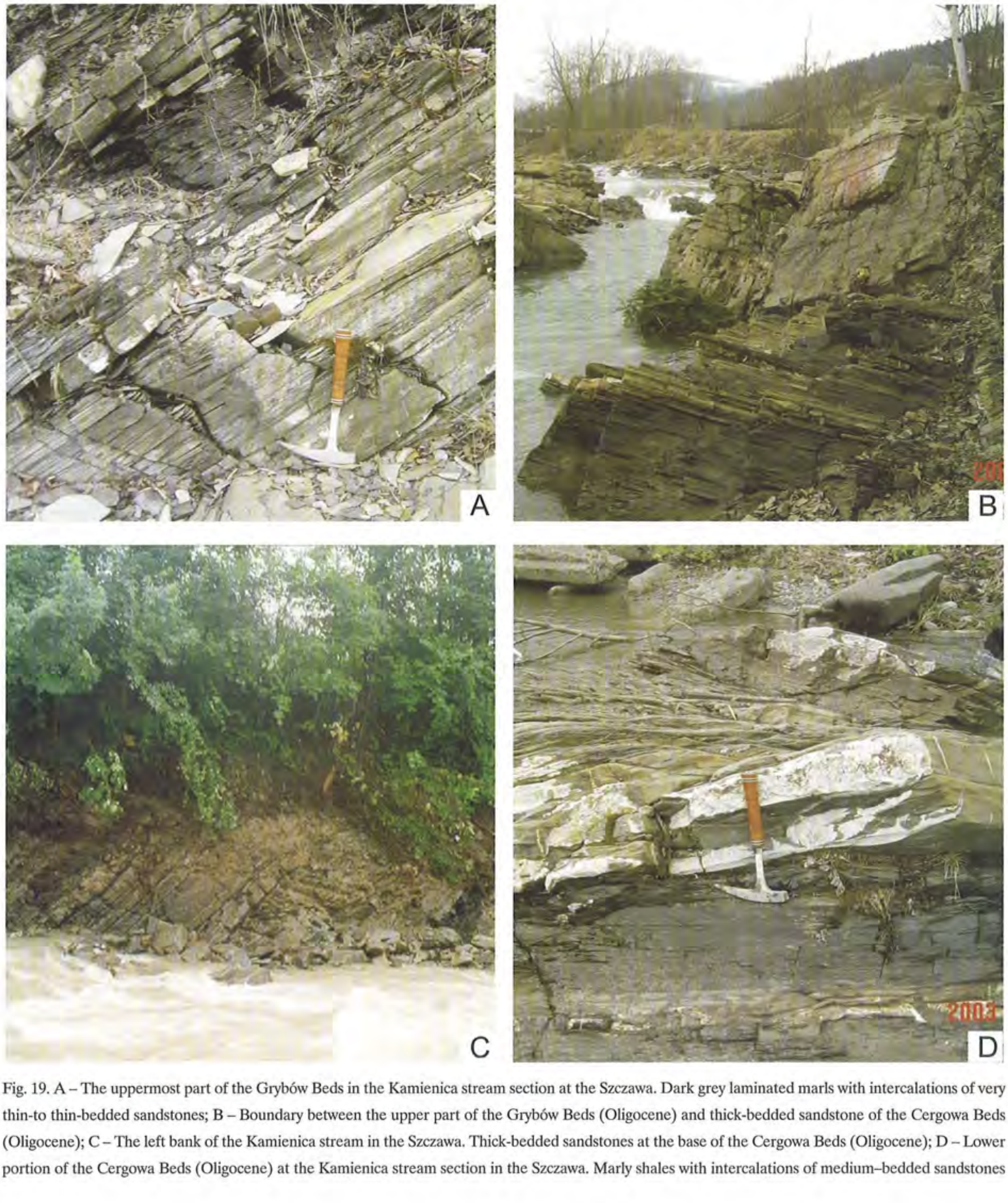


Fig. 19. A – The uppermost part of the Grybów Beds in the Kamienica stream section at the Szczawa. Dark grey laminated marls with intercalations of very thin-to thin-bedded sandstones; B – Boundary between the upper part of the Grybów Beds (Oligocene) and thick-bedded sandstone of the Cergowa Beds (Oligocene); C – The left bank of the Kamienica stream in the Szczawa. Thick-bedded sandstones at the base of the Cergowa Beds (Oligocene); D – Lower portion of the Cergowa Beds (Oligocene) at the Kamienica stream section in the Szczawa. Marly shales with intercalations of medium-bedded sandstones

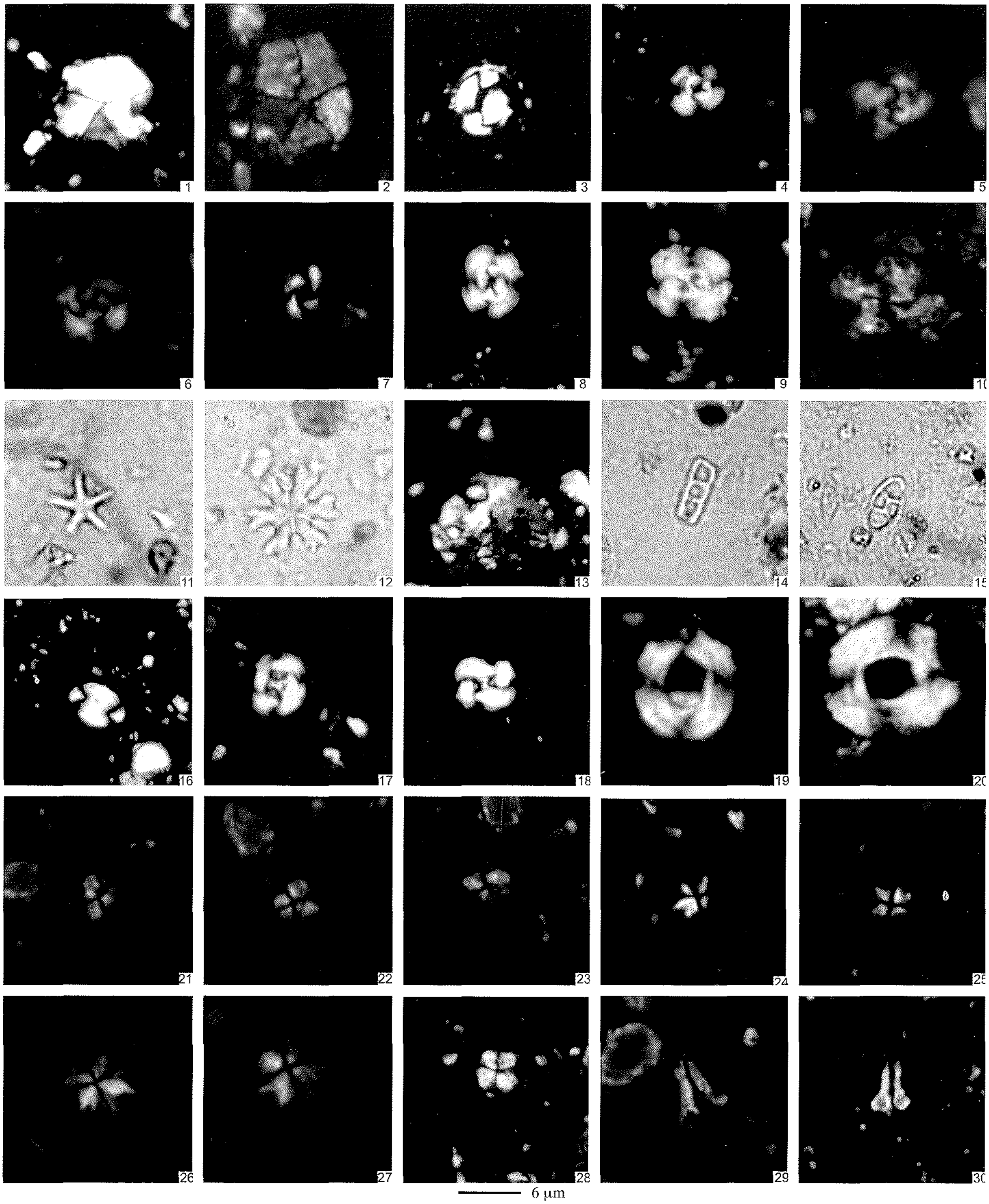


Fig. 20. LM microphotographs of calcareous nannofossils from the Oligocene deposits of the Mszana Dolna and Szczawa tectonic widows. 1 – *Braarudosphaera bigelowii* sample 48/97/N, 2 – *Braarudosphaera bigelowii* sample 61/02/N, 3 – *Coccolithus pelagicus* sample 43/00/N, 4 – *Cyclicargolithus abisectus* sample 31/97/N, 5 – *Cyclicargolithus abisectus* sample 61/02/N, 6 – *Cyclicargolithus abisectus* sample 66/02/N, 7 – *Cyclicargolithus floridanus* sample 39/97/N, 8 - Dictyococcites *bisectus* sample 70/00/N, 9 – *Dictyococcites bisectus* sample 2/01/N, 10 – *Dictyococcites bisectus* sample 70/02/N, 11 – *Discoaster tanii* sample 71/00/N, 12 – *Discoaster deflandrei* sample 70/02/N, 13 – *Helicosphaera compacta* sample 33/97/N, 14 – *Isthmohlithus recurvus* sample 71/00/N, 15 – *Neococcolithes dubius* sample 71/00/N, 16 – *Pontosphaera plana* sample 47/97/N, 17 – *Reticulofenestra lockerii* sample 31/97/N, 18 – *Reticulofenestra lockerii* sample 47/97/N, 19 – *Reticulofenestra umbilica* sample 71/00/N, 20 – *Reticulofenestra umbilica* sample 71/00/N, 21 – *Sphenolithus conicus* sample 70/02/N, 22 – *Sphenolithus conicus* sample 70/02/N, 23 – *Sphenolithus conicus* sample 70/02/N, 24 – *Sphenolithus dissimilis* sample 70/00/N, 25 – *Sphenolithus dissimilis* sample 31/97/N, 26 – *Sphenolithus dissimilis* sample 30/00/N, 27 – *Sphenolithus dissimilis* sample 30/00/N, 28 – *Sphenolithus moriformis* sample 70/00/N, 29 – *Zygrhablithus bijugatus* sample 13/01/N, 30 – *Zygrhablithus bijugatus* sample 33/97/N

are intercalated with thin layers of black, marly shales and thin-bedded, cross-ripple, laminated sandstones. The thick-bedded, coarse-grained massive sandstones have been observed sporadically. The sandstones display palaeotransport from the NE (70°). These types of deposits are about 50 m thick and are followed by couplets, up to 2 m thick of dark-grey, softy-laminated marls and marly shales with sporadic intercalations of very fine-grained, thin-bedded sandstones (Text-fig. 19A-B).

Cergowa Beds

In the middle part of the section (Text-figs 15, 17; 19B-C) occur two layers of very thick-bedded, coarse-grained, channelled, conglomeratic sandstones. These sandstones reveal palaeotransport from the NE (70°). The sandstones are overlain by laminated marls with thin bedded sandstones (Text-fig. 19D). The uppermost part of the section (above the bridge) is composed of dark-grey coloured (yellowish if weathered), massive, hard marls with sporadic intercalations of thick-bedded, Cergowa-type sandstones. The beds are up to 200 m thick.

CALCAREOUS NANNOFOSSIL

Sample preparation

All samples were prepared using the standard smear slide technique for light microscope (LM) observations. The investigation was carried out under LM - Nikon –Eclipse E 600 POL, at a magnification of 1000 × using parallel and crossed nicols. Several of the specimens photographed in LM are illustrated in Text-fig. 20.

Results

The majority of the examined samples yielded a very poor and badly preserved nannofossil material. Some specimens could not be identified because of strong etching and mechanical damage of the placoliths, especially of their central areas. The abundance of particular taxa is usually low. The scarcity of the species most important stratigaphically makes age determinations very difficult. However, some of the samples were rich enough, enabling zonal assignment.

Grybów Beds

In the Grybów Beds nannofossils are poorly preserved and represented by low diversity assemblages with a low number of specimens. Non-calcareous or slightly calcareous shales and marls are barren of nannofossils (Tables 1-2). Relatively rich assemblages are noted exclusively in samples from the Szczawa section.

Rich assemblage was found in sample 71/00/N (Text-fig. 21, Table 1). In other samples most of these species are missing. The important feature of this sample is the appearance of rare *Reticulofenestra ornata*. Higher up in the Szczawa section first appears *Cyclicargolithus abisectus*. Additionally, a rich association was found in sample 31/97/N (Text-fig. 21, Table 1).

Cergowa Beds

Again a relatively rich assemblage comes from the samples of the Szczawa section. A low diversity assemblage with a poorly preserved nannofossil association was found in samples from the Lubomierz section (Text-fig. 21, Table 1). The most important species found in both sections is *Cyclicargolithus abisectus,* accompanied by *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Reticulofenestra lockerii*, *Reticulofenestra dictyoda* and *Reticulofenestra ornata*. Additionally some of the samples from the Szczawa section contained *Helicosphaera euphratis*, *Helicosphaera compacta*, *Pontosphaera multipora*, *Pontosphaera plana*, *Sphenolithus dissimilis* and *Sphenolithus moriformis*. The straigrpahically youngest species, *Sphenolithus conicus*, was found in the uppermost part of the Cergowa Beds in the Lubomierz section.

Krosno Beds of the Dukla Unit

Nannofossils of these units are poorly preserved and are represented by low diversity assemblages with a low number of specimens (Table 3). The nannofossil association from sample 58/02/N does not contain any zonal marker. The other samples are characterised by the co-occurence of *Coccolithus eopelagicus*, *Coccolithus pelagicus*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Sphenolithus moriformis*, *Zygrhablithus bijugatus*. Additionally samples 30/00/N and 33/00/N contain rare specimens of *Sphenolithus dissimilis*.

Biostratigraphical interpretation

For the purpose of biostratigraphic analysis the standard zonation of MARTINI (1971) was used.

The nannofossil association described form the Grybów Beds enabled the recognition of zones NP22, NP23 and NP24. The zone NP22 is documented by a continuous range of *Reticulofenestra umbilica* (LEVIN) follow-

SZCZAWA	OLIGOCENE																																
Lithostratigraphy	Grybów Beds																		Cergowa Beds									Grybów Beds					
Calcareous nannofossil zones Martini (1971)	NP 23	NP 23		NP 24		NP 24		NP 24	NP 24	NP 24	NP 24		NP 24	NP 24		NP 24	NP 24	NP 24		NP 24	NP 24	NP 24		NP 24		NP 24			NP 24		NP 24	NP 22	
sample Nos.	28/ 97/N	29/ 97/N	30/ 97/N	31/ 97/N	32/ 97/N	33/ 97/N	34-37 97/N	38/ 97/N	39/ 97/N	40/ 97/N	41/ 97/N	42/ 97/N	43/ 97/N	44/ 97/N	45-46 97/N	47/ 97/N	48/ 97/N	49/ 97/N	50/ 97/N	51/ 97/N	52/ 97/N	53/ 97/N	54/ 97/N	55/ 97/N	50/ 00/N	51/ 00/N	52-53 00/N	64-67 00/N	68/ 00/N	69/ 00/N	70/ 00/N	71/ 00/N	72/ 00/N
sample abundance	L	L		M		L		L	M	M	M		L	M		M	M	M		M	M	M		L		M			L		M	M	
nannofossil preservation	M	M		M		P		P	M	M	M		L	M		M	M	M		M	M	M		M		M			M		M	M	
Braarudosphaera bigelowii		X	-		-		-		X			-		X	-		X		-				-		-	X	-	-	X	-			-
Coccolithus eopelagicus	X	X	-	X	-	X	-			X	X	-	X	X	-	X	X	X	-	X	X	X	-	X	-	X	-	-	X	-	X	X	-
Coccolithus pelagicus	X	X	-	X	-	X	-	X	X	X	X	-	X	X	-	X	X	X	-	X	X	X	-	X	-	X	-	-	X	-	X	X	-
Coronocyclus nitescens			-		-		-					-			-	X			-				-		-		-	-		-			-
Cyclicargolithus abisectus			-	X	-		-	X	X	X	X	-	X	X	-	X	X	X	-	X	X	X	-	X	-	X	-	-	X	-	X		-
Cyclicargolithus floridanus	X	X	-	X	-	X	-	X	X	X	X	-	X	X	-	X	X	X	-	X	X	X	-	X	-	X	-	-	X	-	X	X	-
Cyclicargolithus luminis			-	X	-		-					-			-				-				-		-		-	-		-			-
Dictyococcites bisectus	X	X	-	X	-	X	-	X	X	X	X	-	X	X	-	X	X	X	-	X	X	X	-	X	-	X	-	-	X	-	X	X	-
Discoaster tanii			-		-	R	-					-			-				-				-		-		-	-		-		X	-
Discoaster tanii nodifer			-		-		-					-			-				-				-		-		-	-		-		X	-
Ericsonia fenestrata			-		-		-					-			-	R			-				-		-		-	-		-			-
Ericsonia formosa			-		-		-					-			-				-				-		-		-	-		-			-
Helicosphaera euphratis			-		-		-					-			-				-				-		-		-	-		-	X		-
Helicosphaera compacta			-		-	X	-				X	-			-				-				-	X	-	X	-	-		-			-
Isthmohlithus recurvus			-	R	-		-					-			-	R	R		-				-		-		-	-		-		X	-
Lanternithus minutus	X	X	-		-		-		R		R	-		R	-	R	R		-		R		-		-		-	-		-	R	X	-
Neococcolithes dubius			-		-		-					-			-				-				-		-		-	-		-		X	-
Pontosphaera multipora			-	X	-		-					-			-	X			-				-		-		-	-		-			-
Pontosphaera plana			-	X	-	X	-		X			-			-	X			-				-		-		-	-		-			-
Reticulofenestra daviessi			-		-		-					-			-				-				-		-		-	-		-			-
Reticulofenestra dictyoda	X	X	-	X	-		-					-			-	X			-				-		-		-	-		-	X	X	-
Reticulofenestra lockerii			-	X	-		-		X		X	-			-	X	X		-	X		X	-		-		-	-		-			-
Reticulofenestra minuta			-	X	-		-		X			-			-	X			-			X	-		-		-	-		-			-
Reticulofenestra ornata	X	X	-	X	-		-		X	X		-			-	X			-			X	-		-	X	-	-		-			-
Reticulofenestra umbilica			-		-		-					-			-	R			-				-		-		-	-	R	-	R	X	-
Sphenolithus dissimilis			-	X	-		-				X	-			-				-		X		-		-		-	-		-	X		-
Sphenolithus moriformis			-	X	-		-	X	X	X	X	-	X	X	-		X	X	-	X		X	-	X	-	X	-	-		-	X	X	-
Sphenolithus pseudoradians			-		-		-					-			-				-				-		-		-	-		-			-
Sphenolithus radians			-	R	-		-				R	-			-				-				-		-		-	-		-		X	-
Zygrhablithus bijugatus	X	X	-	X	-	X	-	X	X		X	-		X	-	X			-		X		-		-	X	-	-	X	-	X		-

Table 1. Calcareous nannofossil distribution in Szczawnica section; R = rare (9-1 specimen/20 fields of view); VR = very rare (<1 specimen/20 fields of view); r = reworked specimen; Estimates of the abundance of nannofossils in samples: H = high (>15 specimens/1 field of view); M = moderate (15-5 specimens/1 field of view); L = low (5-1 specimen/1 field of view); VL = very low (<1 specimen/1 field of view). Preservation of nannofossils: M = moderate (overgrowth; etching or mechanical damage is apparent but majority of of specimens are easily identifiable); P = poor (etching and mechanical damage is intensive making identification of some specimens difficult); VP = very poor (some specimens cannot be identified).

ing the disappearance of *Ericsonia formosa* (KAMPTNER). The disappearance of *R. umbilica* and the presence of *Reticulofenestra ornata* MÜLLER may suggest the presence of zone NP23 (see MÜLLER, 1970, NAGYMAROSY & VORONINA 1992). The FO of *Cyclicargolithus abisectus* is usually found close to the FO of *Sphenolithus ciperoensis*, a marker for the base of zone NP24, and consequently may be used as a proxy of this boundary (MARTINI & MÜLLER 1986). Also found was *Sphenolithus dissimilis* BUKRY & PERCIVAL, first appearing in zone NP24 (see PERCH-NIELSEN 1985).

The nannofossil zones recognised within the Cergowa Beds are NP24 and NP25. The presence of zone NP25 is documented by the FO of *Sphenolithus conicus* followed by a continuous range of *Cyclicargolithus abisectus*, *Dictyococcites bisectus* and *Zygrhablithus bijugatus*. The FO of *S. conicus* has been traditionally used to mark the base of zone NN1, although BIZON & MÜLLER (1979), BIOLZI & *al.* (1981) and MELINTE (1995) reported this species already from the upper part of zone NP25.

The presence of *C. abisectus* and *S. dissimilis* wihin the Krosno Beds from the Dukla Unit, seems to indicate zone NP24 (see MARTINI & MÜLLER 1986, PERCH-NIELSEN 1985).

Palaeocology

Because of extremely low diversity of most of the studied samples, which might be due to dissolution, the ecological analysis is made only for the assemblages from the Szczawa tectonic window.

The assemblages are characterized by the presence of both temperate (*Dictyococcites bisectus, Cyclicargolithus floridanus, Coccolithus pelagicus, Coccolithus eopelagicus*) and typically cold water taxa, such as *Isthmolithus recurvus, Reticulofenestra callida, Reticulofenestra lockerii, Reticulofenestra ornata* (see WEI & WISE 1990, AUBRY 1992, KRHOVSKÝ & *al.* 1992, OSZCZYPKO-CLOWES 2000). In the assemblages of zones NP22 and NP23 also noted are rare representatives of *Helicosphaera*, *Sphenolithus* and of *Discoaster*. These typically warm water indicators, occur, however, only sporadically. Therefore, it is possible to conclude that Oligocene assemblages from the Szczawa tectonic window were dominated by mid-latitudinal species.

According to NAGYMAROSY & VORONINA (1992) *Reticulofenestra ornata, Transversopntis fibula* and *Transversopntis latus* are endemic species, characteristic for the brackish-water environments and limited to the

· GRYBÓW UNIT	OLIGOCENE														?	OLIGOCENE				
sample localities	PORĘBA GÓRNA								KONINKI							LUBOMIERZ				
Lithostratigraphy	Grybów Beds								Grybów Beds							Cergowa Beds				
Calcareous nannofossil zones Martini			NP 23			NP 23				NP 23			NP 23				NP 24	NP 24		NP 25
sample Nos.	41/ 00/N	42/ 00/N	43/ 00/N	44/ 00/N	1/ 01/N	2/ 01/N	3-4/ 01/N	1-3/ 02/N	51-52/ 00/N	53/ 00/N	10/ 01/N	11-12/ 01/N	13/ 01/N	14-16/ 01/N	17-32/ 01/N	62-65/ 02/N	66/ 02/N	67/ 02/N	68-69/ 02/N	70/ 02/N
sample abundance			L	L		M			L				VL				L	L		M
nannofossil preservation			P	P		P			P				P			P		P		M
Braarudosphaera bigelowii	-	-			-		-	-	-		-	-	X	-	-	-	X		-	X
Coccolithus eopelagicus	-	-			-	X	-	-	-		-	-		-	-	-			-	
Coccolithus pelagicus	-	-	X		-		-	-	-	X	-	-	X	-	-	-		X	-	X
Coronocyclus nitescens	-	-			-		-	-	-		-	-		-	-	-			-	
Cyclicargolithus abisectus	-	-			-		-	-	-		-	-		-	-	-	X	X	-	X
Cyclicargolithus floridanus	-	-	X	X	-	X	-	-	-	X	-	-	X	-	-	-	X	X	-	X
Cyclicargolithus luminis	-	-			-		-	-	-		-	-		-	-	-			-	
Dictyococcites bisectus	-	-	X	X	-	X	-	-	-	X	-	-	X	-	-	-	X	X	-	X
Discoaster tanii	-	-			-		-	-	-		-	-		-	-	-			-	
Discoaster deflandreii	-	-			-		-	-	-		-	-		-	-	-			-	X
Ericsonia fenestrata	-	-			-		-	-	-		-	-		-	-	-			-	
Ericsonia formosa	-	-			-		-	-	-		-	-		-	-	-			-	
Helicosphaera euphratis	-	-			-		-	-	-		-	-		-	-	-			-	
Helicosphaera compacta	-	-			-		-	-	-		-	-		-	-	-	X		-	
Isthmohlithus recurvus	-	-	X		-		-	-	-		-	-		-	-	-			-	
Lanternithus minutus	-	-	X	X	-	X	-	-	-		-	-		-	-	-			-	
Neococcolithes dubius	-	-			-		-	-	-		-	-		-	-	-			-	
Pontosphaera multipora	-	-			-		-	-	-		-	-		-	-	-			-	
Pontosphaera plana	-	-			-		-	-	-		-	-		-	-	-			-	
Reticulofenestra daviessi	-	-			-		-	-	-		-	-		-	-	-			-	
Reticulofenestra dictyoda	-	-			-		-	-	-	X	-	-	X	-	-	-	X	X	-	X
Reticulofenestra lockerii	-	-			-	X	-	-	-		-	-	X	-	-	-		X	-	
Reticulofenestra minuta	-	-			-		-	-	-		-	-		-	-	-			-	
Reticulofenestra ornata	-	-	X		-	X	-	-	-		-	-	X	-	-	-	X	X	-	
Reticulofenestra umbilica	-	-			-		-	-	-		-	-	R	-	-	-			-	
Sphenolithus dissimilis	-	-			-		-	-	-		-	-		-	-					X
Sphenolithus moriformis	-	-			-		-	-	-		-	-		-	-	-			-	X
Sphenolithus pseudoradians	-	-			-		-	-	-		-	-		-	-	-	X		-	X
Sphenolithus radians	-	-			-		-	-	-	R	-	-		-	-	-			-	
Zygrhablithus bijugatus	-	-	X		-	X	-	-	-		-	-	X	-	-	-	X	X	-	X

Table 2. Calcareous nannofossil distribution in Poręba Górna, Koninki and Lubomierz sections (Grybów Unit)

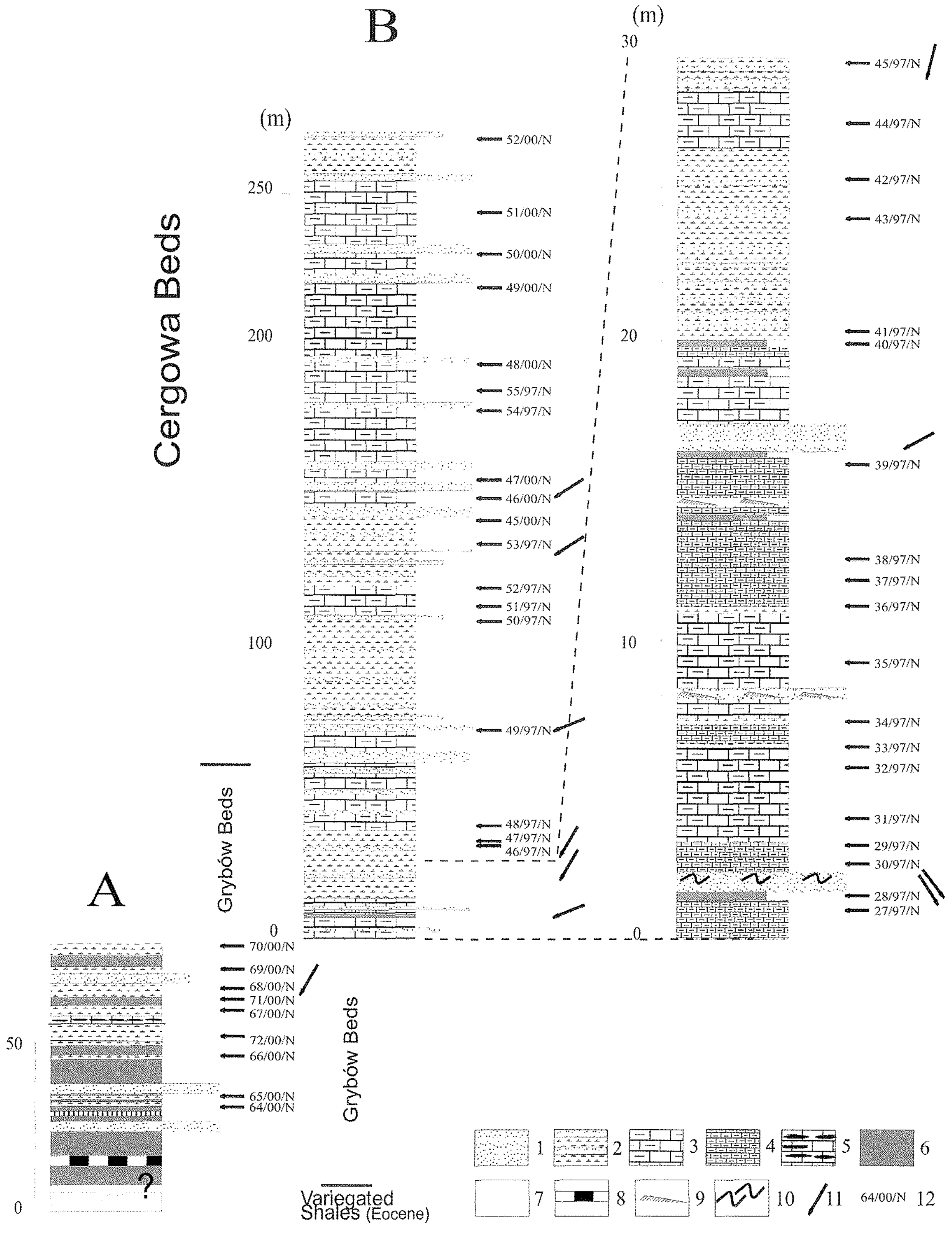


Fig. 21. Lithostratigraphic log of the Grybów Unit in the Szczawa tectonic window; 1 – thick-bedded sandstones, 2 – dark marly shales, 3 – grey thick-bedded marls, 4 – black and grey laminated marls, 5 – spherosiderites, 6 – black shales, 7 – variegated shales, 8 – hornstones, 9 – ripple cross-lamination, 10 – big convolution, 11 – palaeocurrent direction, 12 – samples

DUKLA UNIT	OLIGOCENE																		
sample localities	NIEDŹWIEDŹ						PORĘBA WIELKA									LUBOMIERZ			
Lithostratigraphy	Krosno Beds						Krosno Beds									Krosno Beds			
Calcareous nannofossil zones		NP			NP	NP	NP	NP		NP						?		NP	NP
Martini		24			24	24	24	24		24								24	24
sample Nos.	26/ 00/N	27/ 00/N	28/ 00/N	29/ 00/N	30/ 00/N	31/ 00/N	32/ 00/N	33/ 00/N	34/ 00/N	35/ 00/N	36/ 00/N	37/ 00/N	38/ 00/N	39/ 00/N	40/ 00/N	58/ 02/N	59/ 02/N	60/ 02/N	61/ 02/N
sample abundance		M			M	M	L	L		L		L				VL		VL	L
nannofossil preservation		M			M	M	P	P		VP		M				VP		VP	P
Braarudosphaera bigelowii	-	X	-	-					-		-		-	-	-		-	X	X
Coccolithus eopelagicus	-	X	-	-					-		-		-	-	-	X	-		
Coccolithus pelagicus	-	X	-	-	X			X	-		-	X	-	-	-	X	-	X	
Coronocyclus nitescens	-		-	-					-		-		-	-	-		-		
Cyclicargolithus abisectus	-	X	-	-	X	X	X	X	-	X	-		-	-	-		-	X	X
Cyclicargolithus floridanus	-	X	-	-	X	X	X	X	-	X	-	X	-	-	-	X	-	X	X
Cyclicargolithus luminis	-		-	-					-		-		-	-	-		-		
Dictyococcites bisectus	-	X	-	-	X	X	X	X	-	X	-	X	-	-	-	X	-	X	X
Discoaster tanii	-		-	-					-		-		-	-	-		-		
Discoaster tanii nodifer	-		-	-					-		-		-	-	-		-		
Ericsonia fenestrata	-		-	-					-		-		-	-	-		-		
Ericsonia formosa	-		-	-					-		-		-	-	-		-		
Helicosphaera euphratis	-		-	-					-		-		-	-	-		-		
Helicosphaera compacta	-		-	-					-		-		-	-	-		-		
Isthmohlithus recurvus	-		-	-					-		-		-	-	-		-		
Lanternithus minutus	-		-	-					-		-		-	-	-		-		
Neococcolithes dubius	-		-	-					-		-		-	-	-		-		
Pontosphaera multipora	-		-	-					-		-		-	-	-		-		
Pontosphaera plana	-		-	-					-		-		-	-	-		-		
Reticulofenestra daviessi	-		-	-					-		-		-	-	-		-		
Reticulofenestra dictyoda	-	X	-	-					-		-		-	-	-		-		
Reticulofenestra lockerii	-		-	-					-		-		-	-	-		-		X
Reticulofenestra minuta	-		-	-					-		-		-	-	-		-		
Reticulofenestra ornata	-	X	-	-	X	X			-		-		-	-	-		-		
Reticulofenestra umbilica	-		-	-					-		-		-	-	-		-		
Sphenolithus dissimilis	-		-	-	X			X	-		-		-	-	-				
Sphenolithus moriformis	-		-	-			X		-	X	-		-	-	-		-		
Sphenolithus pseudoradians	-		-	-					-		-		-	-	-	X	-	X	X
Sphenolithus radians	-		-	-					-		-		-	-	-		-		R
Zygrhablithus bijugatus	-	X	-	-	X	X			-		-	X	-	-	-	X	-	X	X

Table 3. Calcareous nannofossil distribution in Niedźwiedź Poręba Górna, and Lubomierz sections (Dukla Unit)

Paratethys region, and are limited to zone NP23 (NAGYMAROSY & VORONINA 1992). In the studied sections these forms do not form the monospecific association (although highly dominated by *Reticulofenestra ornata*) like that known from the East Paratethys (NAGYMAROSY & VORONINA 1992). Moreover, *T. latus* and *T. fibula* were not found at all. The medium-abundant occurrence of *R. ornata*, as well as the lack of *T. latus* and *T. fibula*, may suggest a drop of the salinity, but not radical as described by NAGYMAROSY & VORONINA (1992).

Near the base of NP24 the open-marine, calcareous nannofossil assemblages have developed again. Zone NP24 is characterised by the presence of rich and diversified assemblages dominated by *Dictyococcites bisectus, Coccolithus eopelagicus, Coccolithus pelagicus, Cyclicargolithus abisectus, Cyclicargolithus floridanus, Helicosphaera compacta, Helicosphaera euphratis, Helicosphaera recta, Ponthosphaera multipora, Sphenolithus moriformis* and *Zygrhablithus bijugatus.*

THE YOUNGEST DEPOSITS OF THE STUDIED TECTONIC WINDOWS

The Mszana Dolna tectonic window is composed of deposits belonging to the Fore-Magura Group of units. The western, eastern and southern marginal parts of this tectonic window are occupied by strongly tectonized Cretaceous-Oligocene deposits of the Grybów Unit. The Szczawa tectonic window is composed entirely of the Oligocene deposits belonging to the Grybów Unit.

The characteristic feature of the Grybów Unit, is the presence of the Grybów shales distinguished by UHLIG (1888). These are black, marly, thickly spliting muddy shales, with intercalations of silicified ferrodolostones ("spherosiderites"), with black hornstones at the top (ŚWIDZIŃSKI 1947). These shales are known from all tectonic windows of the Magura Nappe. According to ŚWIDZIŃSKI (1963) there is a similarity between the Menilite Shales of the innermost portion of the Dukla Unit and the Grybów Beds of the Grybów Unit. In the

Ukrainian Carpathians, black calcareous shales, similar to the Grybów Beds were distinguished by VIALOV (fide KRUGLOV 1989) as the Dusina Marls. The Dusina Marls have been incorporated by KRUGLOV (1989) into the Porkulets Unit, which occupied a more internal position than the Dukla Unit. The same marls are also known from the upper part of the Marmarosh flysch succession as the Luh Beds (SMIRNOV 1973).

The Grybów Beds of the Mszana Dolna and of the Szczawa tectonic windows display a specific development. Their lowermost part is dominated by black non-calcareous shales with intercalations of thin- to medium-bedded quartzite sandstones. These shales are very similar to older stratigraphically black deposits known as "black Palaeocene", "black Krosno shales"(see BURTAN & *al.* 1978), or "black Eocene" (see BURTAN & *al.* 1992a), which occupied the intermediate position between the Jaworzynka and Grybów Beds (see Text-fig. 9B in the Koninki section). Only the upper part of the Grybów Beds (above the chert layer in Szczawa section, see Text-fig. 17), characterised by intercalations of black shaly marls and "spherosiderites", can directly be compared with the stratotypic Grybów section (see ŚLĄCZKA & KAMINSKI 1998). The Grybow Beds of the Mszana Dolna tectonic window were assigned to zones NP23 and NP24, whereas in the Szczawa tectonic window (Głębieniec and Kamienica sections), these Beds represent zones NP22, NP23 and NP 24. The upper part of the Grybów Unit is well exposed in the Szczawa tectonic window (Text-figs 15-19). The beds are composed of various kinds of marls and marly shales, intercalated with medium- to thick-bedded sandstones. Their position (above hornstones) can be correlated with the Krosno Beds of the Ropa tectonic window (see SIKORA, 1970) and the Cergowa Beds of the Grybów window (PAUL 1991, ŚLĄCZKA & KAMINSKI 1998). In the Szczawa tectonic window the Cergowa Beds were assigned to zone NP24. In the Mszana Dolna tectonic window the equivalents of the Cergowa Beds were found only in the Lubomierz section. The beds belong to zone NP25, which is the youngest, Late Oligocene deposit found in the studied tectonic windows.

The Cergowa Beds of the Szczawa tectonic window, containing marls and thick-bedded sandstones, display lithological and age similarity not only to the Oligocene Cergowa/Krosno Beds of the Grybów and Ropa tectonic windows, but also to the Oligocene Budzów Beds of the Siary Subunit of the Magura Nappe (see OSZCZYPKO-CLOWES 2001). The Cergowa Beds of Szczawa window as well the Budzów Beds of the Siary Subunit also display the same (from the NE) palaeotransport direction. This suggests that the Oligocene sequences of the Grybów and Siary units could be deposited in the northern part of the Magura Basin.

The central, the most uplifted part of this window is dominated by relatively flat laying Oligocene deposits of the Krosno Formation of the Dukla Unit. The oldest deposits of the Dukla Unit (up to Upper Cretaceous) are known only from three deep boreholes drilled in Poręba Wielka IG-1 and Niedźwiedz-1. In the latter borehole the base of the Dukla Unit, and the top of the Silesian Unit were probably pierced at a depth of 4 km. The youngest deposits of the Dukla Unit belong to the shaly facies of the Krosno Formation, which were assigned to zone NP 24, of the Rupelian age. This age correlates well with that of the Krosno Beds of the southern part of the Silesian (BĄK & *al.* 2001), and Dukla units in the Bieszczady Mts. (OLSZEWSKA & SMAGOWICZ 1977), as well as with that of the Dukla Unit of the Klęczany-Pisarzowa tectonic window (BURTAN & *al.* 1992b, CIESZKOWSKI 1992a).

CONCLUSIONS

The Mszana Dolna tectonic window is composed of deposits belonging to the Fore-Magura Group of units. The central and most uplifted part of this window is dominated by relatively flat laying deposits of the Krosno Formation (Oligocene) of the Dukla Unit, whereas the western, eastern and southern marginal parts of MDW are occupied by strongly tectonized, Cretaceous-Oligocene deposits of the Grybów Unit. The Szczawa tectonic window is built up entirely of the Oligocene deposits of the Grybów Unit. The youngest deposits of the Mszana Dolna tectonic window belong to zones NP 24 and NP25 of the Dukla and Grybów units, respectively. In the Szczawa Grybów Unit the youngest deposits (Cergowa Beds) belong to zone NP 24.

The deposits of the Dukla and Grybów units are covered tectonically by the Cretaceous-Eocene deposits of the Magura Nappe. The Magura Nappe thrust surface, uplifted to 600-700 m above sea level at the margins of the Mszana Dolna and Szczawa tectonic windows, deepens progressively outwards from the windows. Towards the east and west this surface dips beneath 1500 and 4000 m below see level, respectively. At the Pieniny Klipen Belt / Magura Nappe boundary, in the Nowy Targ area, this surface was pierced 3500 m below sea level.

At the base of the Magura Nappe chaotic rocks were recognized. These deposits, from the Poręba Górna section, were interpreted as sedimentary (submarine slump, KSIĄŻKIEWICZ 1958, see also CIESZKOWSKI & *al.* 1987, MASTELLA 1988) as well as tectonic (metamorphic tectonites or "wildflysch", see BURTAN & ŁYDKA 1978, BURTAN & *al.* 1978) terms. According to BURTAN & ŁYDKA (1978) and MASTELLA (1988) the temperature during overthrusting reached 300-350 °C.

In our opinion the chaotic deposits reveal a direct relation to the Magura Nappe sole thrust. This is support-ed by observation of the degree of tectonic deformation, which drastically decreased outside of the Magura thrust, both in the Magura as well as the Grybów successions. During the latest Oligocene period the thrusting of the Magura Nappe onto the Fore-Magura (Dukla and Grybów) sedimentary area began to occur. This process was simultaneous with the formation of the Magura piggy-back basin (OSZCZYPKO *& al.* 1999a, OSZCZYPKO & OSZCZYPKO-CLOWES 2002, CIESZKOWSKI 1992b). The process of overthrusting was probably initiated under the submarine condition, when the front of the Magura Nappe reached the Dukla-Grybów sub-basin. As a result the Magura Nappe, at least 2.5-3 km thick, loaded and sealed under compacted clayey-sandy deposits from the Menilite-Krosno Formation of the Grybów succession. This caused the appearance of an over pressured zone along the contact between the Magura Nappe and the Grybów succession (see also MASTELLA 1988), which was affected by fracturing and frictional sliding.

The deep structure of MDW was recognized by deep boreholes (Text-fig. 13). It forms the culmination built up by the stack of three flat-deeping Silesian, Dukla units, whereas the Grybów Unit, with the reduced thickness, is edged between Magura Nappe and Dukla Unit. In surface exposures the Grybów Unit reveals thrust sheet structure. MDW developed during the Middle Miocene thrusting of the Magura Nappe against its foreland. This duplex like structure is composed of imbricated horses of the Grybów Unit, which developed between two thrust surfaces: the floor thrust surface formed along the frontal ramp of the Dukla Unit and the roof thrust surface related to the Magura Nappe. The same mechanism of the Magura Nappe thrusting was suggested by MASTELLA & RUBINKIEWICZ (1998) of the Świątkowa Wielka tectonic window. From latest Oligocene to late Badenian (9-10 Myr; see OSZCZYPKO 1998) the front of the Magura Nappe progressed towards the north. The last episode of these movements resulted in the development of a sinistral, transpressional strike-slip-fault zone along the front of the Magura Nappe (for example Żegocina zone, see NEMČOK *& al.* 2000).

Acnowledgments

We would like to acknowledge helpful comments by Dr Lilian ŠVABENICKA (Prague) and Prof. Andrzej ŚLĄCZKA (Kraków), the journal referees, that helped to improve an original version of the paper. The authors thank to Mrs E. MALATA for determination of foraminifers. We are also grateful to David CLOWES and Jan GOLONKA for their help in correcting the English text. This paper has been carried out with the financial support of the Polish State Science Foundation (KBN) Projects 6P04D 05521(MOC) and 6P04D 04019(NO).

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Manuscript submitted: 10th June 2003
Revised version accepted: 20th January 2004